FACTORY
MANAGEMENT and MAINTENANCE
L. C. MORROW
Editor

Breakers Ahead

INDUSTRY'S "breathing spell" is almost at an end. Congress will convene early in January, and commotion will be resumed. For an indefinite period, just as prosperity is getting under way, industry must divide its attention between carrying on its business and fending off unsound laws.

Coming up again is the A. F. of L. sponsored thirty-hour week proposal. It is just as impracticable as it always has been.

CODE regulation of industry will be proposed in some form or other. Certainly the administration hasn't given up the idea that industry needs policing. Neither have organized labor leaders. (If management wants some kind of regulation it should go to the meeting called by Coordinator Berry for the ninth of this month in Washington, say so, and tell what kind. If it does not want regulation, it should go to the meeting and say so. Going for the purpose of saying no is more important than going to say yes. Unless there are plenty of noes the regulation will be imposed.)

Amendments to the Social Security Act will be forthcoming. The direction they will take is unpredictable.

New tax legislation must evolve if the soldier bonus is put through or processing taxes are eliminated.

It seems likely that a revamped Textile Control Bill will be offered. The original bill, introduced in 1935, contained a provision that would deny the use of the mails to unlicensed manufacturers.

The Federal Licensing Bill, also introduced in 1935, probably will be brought up again. It would provide for federal licensing of corporations engaged in interstate commerce, limit corporation surpluses, revise hours and wages upward to match efficiency increases resulting from technological development.

Finally, there is the Walsh Bill, to impose minimum wages and maximum hours upon manufacturers doing business with the federal government.

Most of these legislative probabilities have a very definite carry-over of the early depression theory that there was a condition of unbalance between production and distribution which could be corrected by legislating wealth from where it was to where it wasn't.

THERE lies the fallacy that industry must combat. Now that the breathing spell is over, industry must resume its job of trying to convince both legislators and workers:

That what is not produced cannot be distributed.

That low prices are necessary for wide distribution.

That enormous government expenditures cannot help but increase prices.

That it still is impossible to legislate into the hands of workers more than the value of production justifies.

Hackneyed though they are, there are just two words that express what is required of industry. They are Cooperation and Leadership.

Are you helping your Congressman to get facts about industry before he goes back to Washington?

Buick's $15,000,000 Bid

Goes after 1936 business with quickest of quick tricks—a plant completely revamped for quality production at low cost

Based on an interview with
HARLOW H. CURTICE
President, Buick Motor Company

WHEN Harlow H. Curtice relinquished the presidency of the A. C. Spark Plug Company (General Motors subsidiary) to take over the command of Buick in 1934, it was with a single purpose in mind —to re-establish Buick's old position in its price class. The company had taken a beating. Its output fell in 1933 to 40,000 units, less than 20 per cent of the 1929 volume. As a stop-gap, the Model 40 low-priced Buick was introduced last year, but practically no important changes were introduced in the 1935 standard models. Instead, every effort was directed toward bringing out a really "hot" car in 1936.

Better Cars at Right Prices

The general idea was to produce an entirely new series of cars that would represent the best in engineering practice, pleasing body contours, and appointments, and to offer them at attractive prices.

It was to be a completely new series, engineered for low-cost production. No limit was set on engineering changes, or on the amount of money that would be spent in plant changes and for new equipment, as long as the main objective of stimulated sales could be attained.

Mr. Curtice has no set formula that is rigidly applied to determine when it is most economical to throw out old equipment and buy new machinery. Each proposal is judged on its own merits, but it must satisfy one or more of these four primary conditions:

1. Cut costs;
2. Reduce maintenance repairs;
3. Improve quality; or
4. Improve working conditions.

There is nothing new about the principles involved. What *is* new, is the fact that the theory was actually put into practice on a grand scale throughout the entire works.

Production executives began to ask machinery manufacturers for proposals. The layout department got busy. The master mechanics division co-ordinated the two and supplied the technical details. Then they all marched up to the front office, still skeptical enough to believe that if they proposed $15,000,000 worth of changes, $5,000,000 might get by. Mr. Curtice approved practically all of them; the accumulated depreciation reserves of the company were there to be drawn upon.

GMC Depreciation Procedure

As a rule, General Motors lets each unit manager run his plant much as he sees fit. There are a few corporation policies, however, that are rigidly applied throughout. One of them is depreciation procedure, which of necessity must be uniform for income-tax purposes, as well as for coordinated accounting. The practice is to charge off as yearly depreciation 10 per cent of the original cost of the equipment. Although a machine may pass its tenth year, it is still burdened with the same depreciation.

In one respect this procedure is almost a necessity in the automobile industry, because the older machines tend to balance the high rate of obsolescence on the many special-purpose machines that become just so much scrap after an important model change.

Why "Rent" Old Equipment?

On the other hand, if a plant manager has on hand a lot of old equipment written off the books, but still carrying a heavy burden, he feels that this overhead will be better spent on a new piece of equipment. Assuming that capital is readily available, it almost becomes a renting proposition. Who, for example, would want to rent an old house with ancient plumbing when a thoroughly modern dwelling could be leased at the same price?

If, by the purchase of one new machine, the management can scrap or sell two old ones, the chances are that the depreciation charges will be lessened. Applied on a large scale, floor space is reduced, and the idle space created can be turned over to other uses—perhaps taking care of the greater volume obtained through offering greater value at a lesser price.

Is it any wonder, then, that Mr. Curtice set no limit on what could be spent on modernization? If he had, he would have automatically set a limit on what could be gained in cost reduction and improved quality.

Changes made during the past summer, including tooling costs that must be absorbed over a single model, cost close to $15,000,000. But this is not the end. A continuing policy now in effect will make mod-

ernization a month-by-month procedure. It will not be necessary in the future to spend a quarter of the capital investment in plant and machinery in a single year. This grand gesture represents delayed replacement which would normally have been extended over the last five years.

From 4,700 to 14,000 Employees

Naturally enough, with cost saving in mind, there have been numerous instances where the number of men or the man-hours on a group of operations have been reduced. In one department, for example, half the workers are producing twice the volume of a year ago. Yet, because of the greater volume of business made possible by the enhanced value of the product, total number of workers on the payroll has been greatly increased. A year ago there were 4,700; today there are over 14,000.

Buick's modernization program was a mass attack from all angles. The primary objectives have been stated. These are some of the channels through which the objectives are being attained:

1. Purchase of new equipment to cut costs, to improve quality;
2. Rebuilding and retooling of existing machines;
3. Rearrangement of existing machines and conveyors;
4. Reduction of number of machines;
5. Smoother flow of materials and parts in process;
6. Reduction of waste;
7. Increase in volume (as related to costs).

Simplification of product is another main channel of approach to cost reduction in the manufacturing departments. Buick policy has definitely tended in this direction. In place of the former 26 models, there are now fourteen, spread over four series. Instead of four engine sizes, there are now only two. Changes like these are reflected throughout the plant. Foundry production is simplified, forging practice facilitated, and especially in the machine shop is the way made clear for efficient layout.

Summary of Machinery Changes in Four Buick Divisions

Shop or Plant	*New Machines Purchased*	*Old Machines Relocated, Surplused, or Scrapped*
Foundry	**61**	**419**
Forge	**39**	**213**
Motor	**98**	**3,218**
Transmission	**190**	**2,118**
Total	**388**	**5,968**

Chance for Fresh Start

When the number of components is reduced, and the production volume of what remains is increased, it means that much old equipment can be scrapped and the best of existing equipment rebuilt and retooled. Furthermore, the acquisition of high-production, special-purpose machine tools then becomes more readily justifiable on the basis of tangible savings in costs. Such important engineering changes give production departments a chance literally to sweep the boards clean and start out afresh, drawing upon a stock of new, rebuilt, and existing machinery.

In brief, this was the situation that confronted Buick operating executives, and they made the most of it. To the layout and master mechanics departments, it meant that nearly every machine in the plant could be considered unbolted. They began to shove around the cardboards in an effort to obtain the ideal arrangement of machinery and materials-handling equipment. New machinery came in by the carload, and for more than one machine-tool builder it looked as if the depression were over.

THIS is the first of three articles. The other two will tell exactly where Buick's $15,000,000 went

If the worker only knew—

Would he want the 30-hour week?

CHINNING lazily with big Ed alongside the 72x72x30 planer in the after-lunch smoke, Sam set off the fireworks without intending to do so.

"What you going to do with that extra 10 hours, Ed?"

"What 10 hours?"

"The ones you get when we work only 30 hours instead of 40. There's a bill going through Congress, you know."

"No, I don't know, Sam—and I hope not."

"You mean you don't want shorter hours? You must be a glutton for punishment. Thought you'd like the extra time for reading—although I don't see what good all those high-brow books do you."

If I Worked Only 30 Hours

"No, I figure that I like to loaf as well as anybody. And I surely like to study, as you say. But I'm not making any more jack than I need right now. If I worked only 30 hours——"

"Wait a minute, Ed. You don't understand. You'd get the same as you're getting now. The bill says so. And a lot of other people would get jobs to do the work we're doing now in that extra 10 hours."

"Oh, yeah? Where's the money coming from?"

"That's easy. The company's got plenty of money. And if they won't foot the bill instead of taking so much for themselves, let 'em raise prices. They can get it back."

"That's an idea, Sam, but it isn't altogether clear to me. In the first place, the company probably doesn't have the money. Just consider that only about 16 per cent of all corporations made any profit in 1932. Things are better now, but there are back bills to be paid. In the second place, if we raised prices everybody else would have to do the same thing, and first thing you know we'd all be eating tripe instead of steak. How would you feel if the old pay check didn't reach?"

. . . when cigarettes went to 17c. you began to roll your own

"But I'd be willing to pay something extra for the extra time, Ed. I don't want it all."

"No, you're not hoggish, I admit that. But look here. You know as well as I do that when prices get so high you quit buying. You won't pay over $20 for a suit. And when cigarettes went to 17c. you began to roll your own. And you quit beer because you thought you ought to get it for a nickel. And your wife joined that meat strike three weeks ago because prices went up."

"But, Ed, those prices were too high. There isn't much labor in any of them. Somebody was just sticking it on."

"Not much labor, you say? What is anything, except labor? Everything we use in this world comes out of the ground. The only thing that makes it usable is the labor added. Isn't that so? Take these castings you and I plane all day. They were all ore once upon a time. Labor mined it, shipped it, changed it into pigs, melted them, poured the castings. Labor made the machinery for mining, the cars and locomotives for shipping, the furnaces for smelting, the cupolas for pouring—everything that went into the making of these castings. Now, just add one-third to the labor cost all along the line and see where you get."

Suppose you did split the remaining 17 per cent among the workers; each one would get mighty little

Labor Gets Most of Income

"But how about the bosses, Ed? It wouldn't hurt my feelings if they took less and gave us more."

"No, that wouldn't worry me any either, Sam. But I don't think it would make much difference. I happened to see a table recently, in some report or other, that surprised me. It showed that in plants like ours—

the manufacturing industries—labor got 83 per cent of all the money paid out for wages, salaries, and other forms of income. Suppose you took all of the remaining 17 per cent and split it up among the workers. Each one would get mighty little."

"You seem to have an answer for everything, Ed. 'Bout time for the whistle, I guess, but answer one more. If there is only so much work to be done, why not divide it up among all the people that can work and let it go at that?"

Plenty of Work to Be Done

"I knew you'd ask something like that. Reams have been written about it. But look at it this way, Sam. There isn't just so much work to be done. The amount of work this country does depends upon just how well it wants to live. You know that 50 million people might as well drive cars as 25 million. And several millions more would like to have radios, and moving picture machines. Well, they can all have them if we'll work to get them.

"But only certain people can do some kinds of work. How many men (or women) could run that big planer of yours? And what will happen if fellows like you, and our expert miller hands, and tool makers, and assemblers, are not permitted to work more than 30 hours a week? Or have to be paid so much that the company can't afford to hire them? We're not going to have the machines to make the autos and the radios to go 'round. And the fewer we make the higher they'll have to be sold and the fewer the customers. And that means plants shutting down. And what good 's a 30-hour week then?

"I tell you, Sam, it's a serious question. Looks good on the face of it, but ain't so good underneath. I hope that a lot of fellows like you don't set up a howl for it, because I think it's going to be bad for you if you get it."

"But it wasn't bad for workers, Ed, when hours were reduced from 60 to 54 and then to 48 and 40. Why not go further down or, if your argument is good, why wouldn't we all be better off if we went back to 60?"

"My idea on that, Sam, is that, as we develop machines to take over the work, hours naturally get shorter while we still make as many things as we did for people to use. But it's a slow process—takes time. Some day we'll not work any more than 30 hours—maybe not that much. But I'm all for letting the shorter hours come about naturally instead of all at once by law. See what I mean?"

"I think so, Ed. Thanks a lot. You've maybe changed my mind. There goes the whistle. So long."

Your Congressman wants to know at first hand why industry should not be further taxed, and why it should not be saddled with additional labor laws. Are you telling him before he goes back to Washington?

Reprints of this article, in pamphlet form, suitable for distribution in pay envelopes, can be secured at relatively small cost

Detroit Moves to Train Apprentices

DETROIT industries are not unaware of the growing scarcity of skilled help, are in fact taking definite steps to revive apprentice training on a city-wide scale.

Last February the Detroit Manufacturers' Committee on Apprenticeship Training began work on a plan designed to "sell" a training program to local industries. On October 29, 75 industrial executives endorsed the Committee's report, adopted a resolution urging Detroit manufacturers, large and small, to establish apprentice training plans.

Headed by H. W. Boulton, Industrial Relations Manager, Murray Corporation of America, the Committee included John M. Amiss (Chrysler), M. A. Clark (U. S. Rubber), M. A. Heidt (Budd Wheel), L. R. Judson (Timken-Detroit Axle), H. J. Roesch (Briggs), Whiting Williams (General Motors), Ray Booth of National Metal Trades Association, and O. F. Carpenter, representing the Detroit Board of Education.

The Committee pointed out that Detroit is a city in which roughly half of the working population is employed in factories. Many of these workers are unskilled, but they must be supervised by skilled men. Machinery must be maintained by skilled men.

3,600 Every Year

Based on the 1930 census, there were 66,654 workers engaged in the skilled trades—such as machining, pattern making, welding. Assuming that 5 per cent of these men are lost annually through old age, death, promotion, and absorption into other occupations, there should be a replacement of 3,600 of these workers every year. Detroit has trained practically no apprentices during the past five years—except those turned out by the Henry Ford Trade School. Yet as raw material there are available some two-thirds of the boys who enter the public schools but for one reason or another have to drop out before completing their high school work. Many of these boys can be trained for worth-while jobs in the skilled trades.

What should an apprentice be taught? Where may he get coordinated academic training? These are some of the questions answered by the Committee in its report. The following procedure was suggested:

1. Determine which departments can use apprentices.

2. Lay out a schedule of work to be mastered by each apprentice.

3. Appoint a sympathetic supervisor and make him responsible for coordinating and carrying out the training plan.

4. Contact the Committee for further assistance.

Incidentally, the 75 executives who endorsed this plan counted noses, found that 25 of their number had served time as apprentices.

Rock garden, said to be America's largest, at Olson Rug Company, Chicago

People remember "the plant with the good-looking grounds"—and, other things being equal, may be counted on to buy its products. That's the strictly utilitarian angle from which to view the business of landscaping factory yards. To it add probable increase in worker morale and possible improvement, however slight, in quality of product. There is left little excuse for neglecting external appearances

Didn't Have to Build, Because—

Modern materials handling equipment made it a relatively simple matter to attune yesterday's plant to the faster production tempo of today

ARTHUR PIEL
Director in Charge of Mechanical Equipment
Piel Brothers, Brooklyn

WITH the repeal of the Eighteenth Amendment we and all the rest of the brewers who had retained their plant properties during prohibition were faced with the immediate task of adapting old facilities to modern production methods. As in any other manufacturing enterprise, every phase of plant operation had to be studied with a single thought in mind—how to reduce unit costs to the point where the product could be sold not only at a price the consumer was willing to pay, *but also at a profit.*

The modernization of our kegging operations is a case in point. We were still rolling kegs on skids.

Now it is perfectly possible to roll a keg on its bilge. Theoretically, a man loads the kegs on a wooden skid and away they go. Watch the operation, however, and you will see that the man does more than simply load; he frequently has to travel the length of the skid to eliminate jams or to pick up kegs that have fallen off. Also, with every change of direction it is necessary to have an operator transfer the kegs from one skid to another. And last, the skid must be sloped, which means variations in heights and lifts.

Not Good Enough

Which is not to say that a skid system of handling kegs does not work. It does—but not well enough. With us the trouble lay in the fact that our racking department—where kegs are filled—had a capacity of 1,000 kegs a day, but we could not move kegs into it or out of it anywhere near fast enough.

First we thought we should have to tear down and rebuild this part of the plant. The physical characteristics of the buildings—location of loading and unloading points, difference in elevations, for instance—seemed to preclude a satisfactory solution. A study of the situation, however, proved to us that, when you own old buildings, the right handling equipment, properly selected and designed to do the specific job, will often correct what look like fatal errors in plant geography and topography.

Photographs from Alvey Manufacturing Company

Last cogs in the Piel keg-handling "machine" are two automatic rigid arm conveyors that lift kegs from cellar and discharge to loading platform. They are marked as No. 8 and No. 11 in the layout plan shown on the two following pages. This photograph was taken from the spot marked with a circled 6

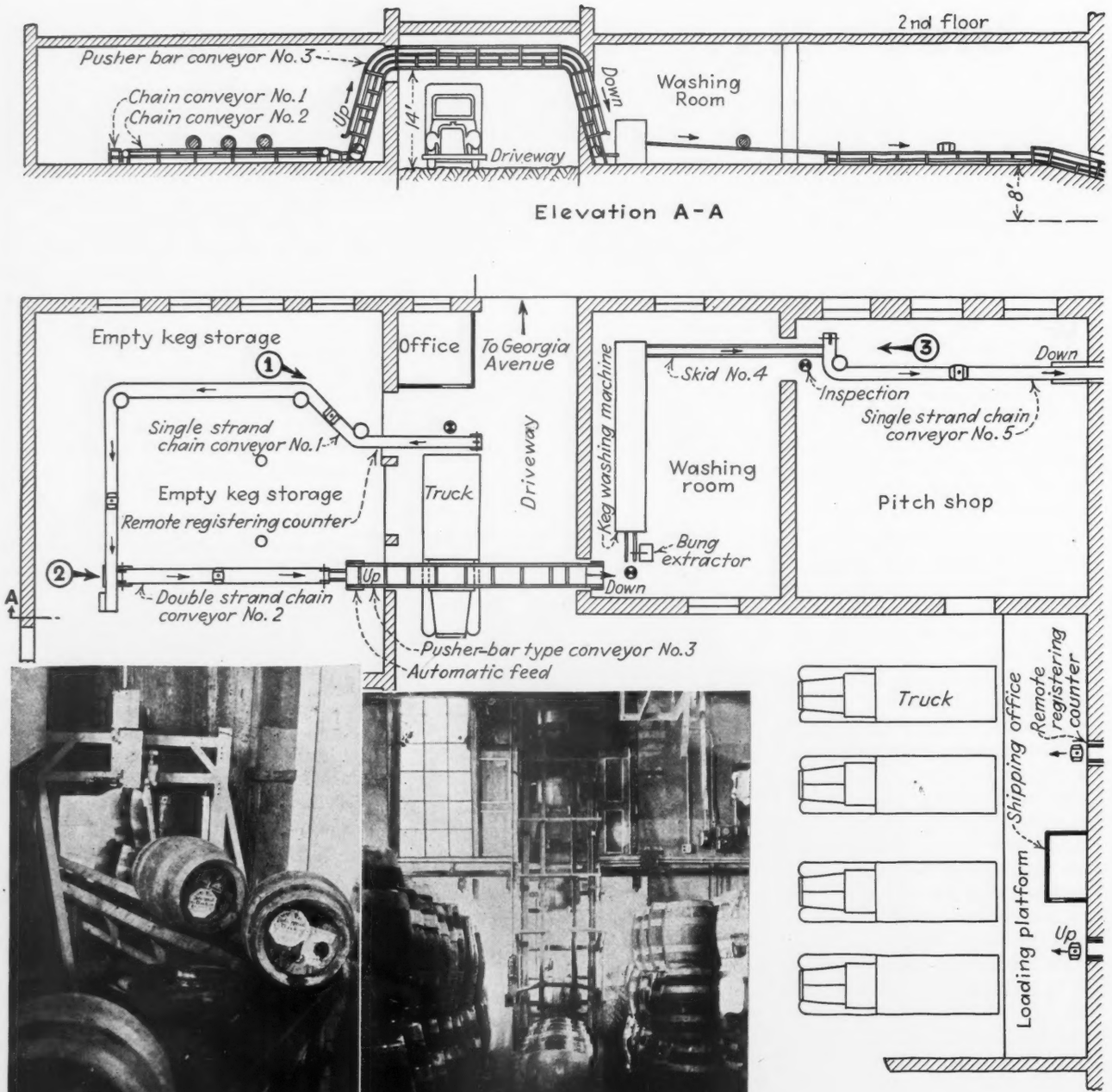
Further study showed, too, that handling must never be treated as a series of totally unrelated moves, but rather as a complete system—in the same sense that the New York Central or the Pennsylvania is a system.

Sketch Tells Story

Well, turn the page and look at the layout sketch. You will see that we installed a complete handling system that starts out as a single-strand chain conveyor, soon turns into—for reasons that will become apparent—a double-strand affair, and finally resumes its original form. Sandwiched in where needed are pusher-bar and rigid-arm conveyors. And, if you look carefully, you will even see three brief sections of old-fashioned skids that simply would not be eliminated.

The layout indicates the point of unloading, empty keg storage, driveway (which had to be climbed over), location of keg washer, rackers (where kegs are filled and bunged), filled keg storage, and finally loading. Each conveyor is marked with a number and will be so referred to in the ensuing description. The photographs that accompany the layout are also numbered on the drawing, and will be referred to in the text that follows as Figure 1, Figure 2, and so on. Arrows point the direction in which the camera was facing in each instance.

This is the way the system works. A truck full of empty kegs drives in, backs up, and unloads direct to Conveyor No. 1. Kegs are placed on it endwise, and as they enter the build-

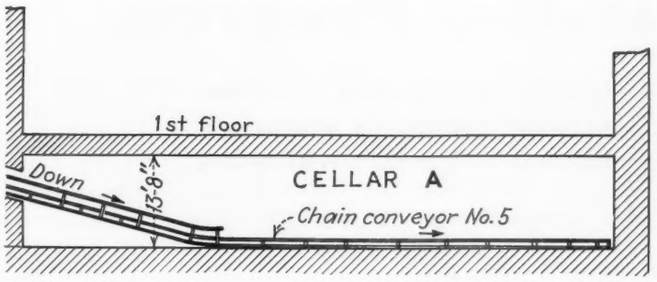


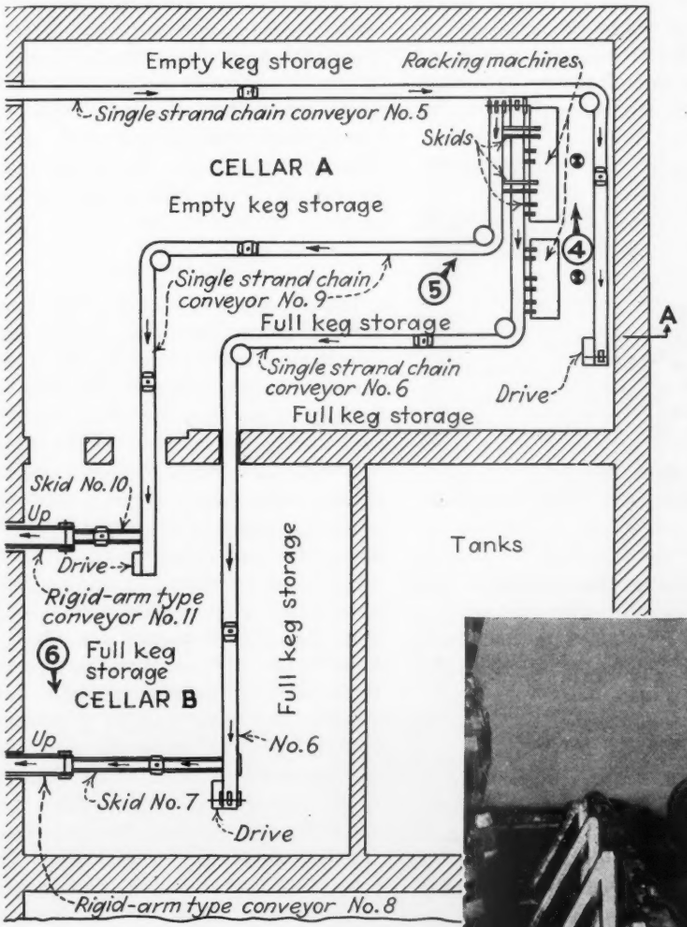
Circled number and arrow indicates spot from which each photograph was taken and direction in which camera was pointed

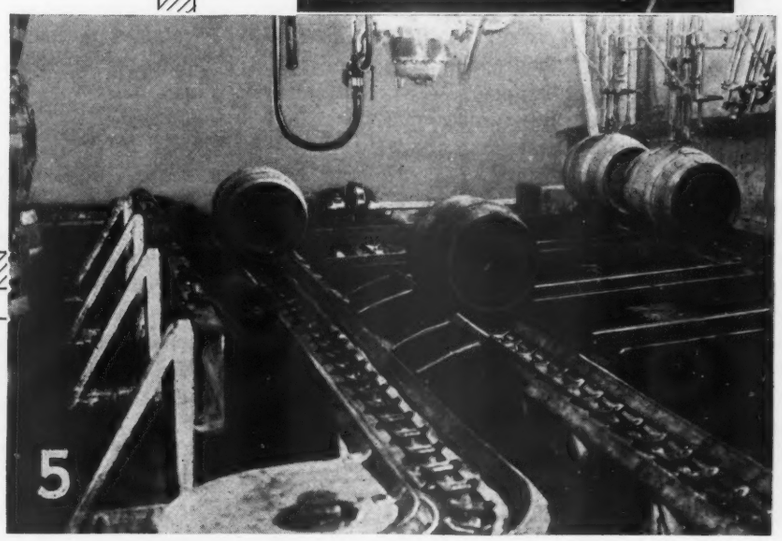
ing (Figure 1) are automatically counted. This electric counter is located right over the opening, makes a separate count of half and quarter kegs, has a remote registration in the checker's office.

Conveyor No. 1 is the single chain type, runs horizontally, and can turn corners. Hence it was possible to make two 45-degree turns and one 90-degree change of direction, thus circling the empty keg storage area. Kegs are supported by the chain, and if they have to be stored are easily lifted off and stacked close by.

When the kegs reach the third side of the storage area, they are automatically transferred to Conveyor No. 2. This is the double-strand type (see Figure 2) and the kegs ride it crosswise. Reason for this change is because Conveyor No. 2 leads to a pusher-bar elevating conveyor which could not handle the kegs lengthwise. Located along Conveyor No. 2 are spring nozzles to loosen the labels and wet the heads







of the kegs. Operators work alongside.

Conveyor No. 3—the pusher-bar conveyor—had to be inserted at this point because empty keg storage is on one side of the driveway, while washing and all subsequent operations are on the other. In other words, the kegs have to be lifted, moved across the area, and then lowered to the bung extractor in the washing room. If this is not entirely clear, refer to the elevation shown directly above the layout sketch.

This pusher-bar elevating conveyor consists of two chains with crossbars at regular intervals. Crossbars are equipped with rollers. Kegs feed in from Conveyor No. 2, and are rolled vertically, then horizontally, along a track runway by the pusher bars behind them. Conveyor No. 3 is shown in the background of Figure 2.

Conveyor No. 3, as previously stated, discharges kegs at the bung extractor. The operator makes only a quarter turn to transfer a keg from the conveyor to the extractor.

Kegs come out of the washing machine at right angles to one of the skids which I said would not be eliminated. Reason for sticking to the

(Continued on advertising page 44)

Used in Weston instruments as bridge insulators to support the jewels that form the bearings for moving coils, these bushings may be the smallest Bakelite pieces ever molded. Compare Britannica, Jr.'s case.

Plastics Progress

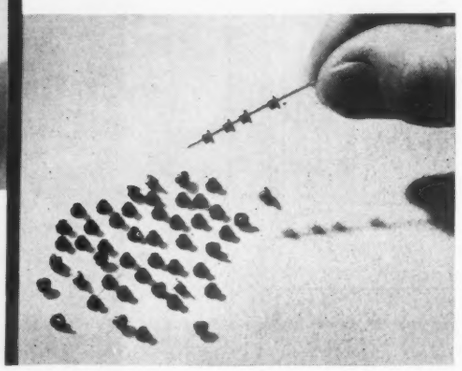
Invites speculation on what drastic changes in materials the next 25 years will bring

LEWIS K. URQUHART
Associate Editor

TWENTY-FIVE years ago — on November 3, 1910, to be exact— *The Electrical World* carried the first advertisement of "Bakelite, the Synthetic Insulating Substance."

Bakelite has long since outgrown that early limiting designation. It has come a long way since 1910. It and other materials of the phenomenal phenol persuasion are so important to industry today that, as Bakelite celebrates its Silver Anniversary, *Factory* would indeed be remiss in its duty to readers were it to neglect the opportunity of chronicling phenolic progress over the past quarter of a century. And if, in the chronicling, Bakelite materials are mentioned to the seeming exclusion of the other phenolic resins, charge it up to the very human desire to assist in the birthday festivities, and remember that Bakelite progress is phenolic resinoid progress. In other words, substitute your favorite phenol *ad lib.* in most of what follows.

First general use of Bakelite in the electrical industry, as may be deduced from the ad in *World*, was in the form of varnishes for coil impregnation and transformers. Shortly after came a number of molded applications—for instance, meter covers, switch plates, indicator switches. A resinoid cement for lamp basing appeared in 1921. The same year, Bakelite was used for circuit breaker insulation; a year later, for elevator dashpots; in 1923, for attachment plugs.



Came the Deluge

Followed a regular avalanche of electrical uses and applications—laminated or molded parts for such familiar household appliances as toasters, irons, vacuum cleaners, washing machines, as well as for countless other uses where the dielectric strength of the material is so necessary. Today Bakelite in one form or another is making it safe and convenient to use electric current —all the way from the central station with its panels, switch handles bus bar insulators, lead-in tubes, and arc shields right down through the transmission lines to the points of consumption. Not only that, but where eye appeal is important, as it is in so many products, Bakelite adds color and beauty to those strictly utilitarian virtues that are too well known to require listing here.

That, in briefest form, is the log of Bakelite's progress within a single industry. The account has been swiftly outlined because it provides the skeleton on which we might hang the clothes of many another industry. Some years ago it was Bakelite's proud boast that it was used in 43 different industries. We should have to do no little scratching around today to uncover 43 that do *not* use it.

2,000 Varieties

Indeed, we find today more than 2,000 Bakelite materials going into countless products and applications. There are cast resinoids for costume jewelry and for chemical beakers that resist hydrofluoric acid; molding materials for high-frequency insulation or for rayon spinning buckets; laminating varnishes for decorative wall paneling or for silent automotive timing gears; heat-hardenable lacquers for razor blades or hardware; cements for electric light bulbs or brush bristles; resins for air-drying paints and varnishes; bonds for high-speed abrasive wheels; flexible resinoids used for waterproofing raincoats and adhesive tape; bonds for plywoods and veneers; resins for printing inks.

This might go on and on. The list is inclusive enough, however, to indicate the diversity of Bakelite materials and their importance to industry as it is set up today.

Take Rayon

How much industry depends on the whole family of phenolic resinoids is nowhere better illustrated, perhaps, than in rayon manufacture. In its early days the industry had spinning bucket trouble. Buckets were metal, rubber covered, had to operate at high speeds in contact with sulphuric acid, sulphur, and carbon sulphide fumes. It was a short life and a gay one. Buckets lasted only two or three months. Today, on the other hand, molded plastic buckets are produced at one-third the cost of the old

Uncertainty as to legislation holds back modernization, further retards low-cost production, therefore delays prosperity. Are you telling this to your Congressman before he goes back to Washington?

buckets, can be operated continuously at 6,800 r.p.m., 24 hours a day, 7 days a week. Average life is 4 years.

The automotive industry? It is no news to most of us to be told that there are more than 50 Bakelite applications in the electric system alone of the modern trouble-free car—50 good reasons, if you please, why today's car *is* trouble-free.

Sample Any Industry

Nor is it news that a partial list of molded and laminated parts must include instrument panels, timing gears, steering wheels, running boards, magneto couplings, robe rails, ignition locks, door lock buttons, ash trays, cigar lighters, vanity cases, heaters, and parts of the auto radio.

Similarly, if we sampled dozens of other industries—dipped into paints and varnishes, for instance, tuned into radios, or scratched among the abrasives—we should come up each time with a list as long as our arm, and each list would serve only to emphasize the extraordinary degree of consumer acceptance to which the phenolic resins have attained in the short space of 25 years.

This is not to say that these materials have never known sales resistance. Rather is it to say that research has been constantly on the job developing new materials for old applications, and new applications for old materials.

Sometimes it has taken years. One of Bakelite's primary objectives was the creation of better furniture varnishes based on phenol-aldehyde products, but it was a dozen years and more before a successful 100 per cent phenolic oil-soluble resin was introduced to the trade.

As early as 1914, to cite another instance, it was apparent that Bakelite resinoids had most of the properties desired in a good denture material. It looked like a simple job of choosing the resinoid that had the most good qualities. But that was only the first step. The confidence of the dental profession had already been shaken by too hasty introduction of new materials, and to cut a long story short it was not until 1933, after nearly 20 years of research, that Bakelite Corporation announced Luxene, its new translucent, pink denture material.

Or take the cast resinoids. Back in 1909 Bakelite was supplying them in sheets, tubes, rods, and special shapes to fabricators who fashioned them into pipe stems, cigar holders, umbrella handles, buttons, buckles, and costume jewelry. Soon the demand grew for an even greater variety of hues and colors, translucent and transparent. Now the latest is a two-tone process whereby a variety of individual colors may be cast into one form. So—bracelets, buckles, and such like may now be fabricated in two or more colors.

Shorts, halters, capes, beach rolls, are made of Revolite, the Bakelite-impregnated cloth that is permanently flexible, resists water, chemicals, alcohol, plus a good bit of wear and tear

And Last, Revolite

One final example of where research has led Bakelite and we shall leave it to quiet contemplation of the customary cake with its 25 candles and a twenty-sixth to grow on.

It is the story of its collaboration some years ago with Johnson & Johnson in the development of special resinoids suitable for treating adhesive tape and making it waterproof, and the resulting announcement of Drybak Band-Aid in 1932. The advantage of treating other materials with these special resinoids became apparent, and Johnson & Johnson soon formed the Revolite Corporation to manufacture flexible, waterproof fabrics into which the resinoid is forced so that it becomes an integral part of the material. Today Revolite fabrics are being used in the manufacture of sportswear, pillows, chintz draperies, and upholstery. The fabrics are easily washed with a damp cloth, and are resistant to common acids, alkalies, and alcohol. As another outgrowth of this special development, the Revolite Corporation has recently introduced new types of laminated materials for industrial applications.

Once we titled an article "People Like Plastics." They certainly do—and to that simple phenomenon must be attributed much of the success of Bakelite and the other phenolic resins. Credit the rest of that success to the sterling characteristics and exemplary behavior of the materials themselves—and to twenty-five years and more of persistent, forward-looking research.

Car Makers Try to Stabilize

Will fall announcements of new models even out production in the automotive industries?

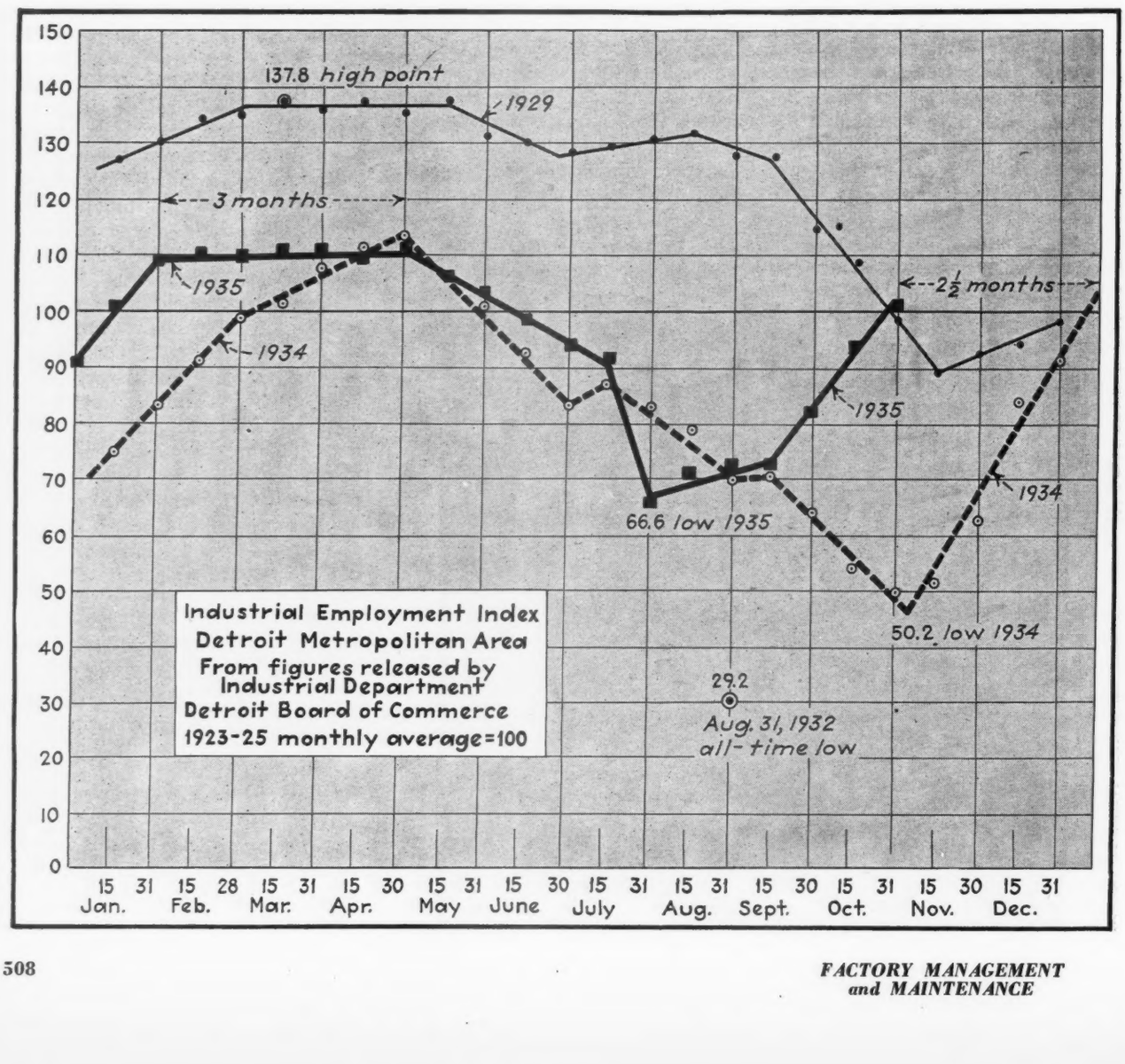
STATISTICIANS can best answer that question a year from now. Present figures on industrial employment in Detroit and environs show, however, what the telescoping of 1935 and 1936 production has already done in the way of stabilizing payrolls.

The accompanying chart was compiled from data released by the Detroit Board of Commerce. By an index number, industrial employment is shown as of the 15th and 31st of each month. Monthly average for the years 1923, '24, and '25 has been taken as the base of 100.

These curves for the past two years indicate that, whereas in 1934 there was no period of even two weeks when employment was stabilized, for three months in 1935 the curve is practically flat. Bottom was struck at an index number of 66.6, July 31, 1935, as against a low of 50.2 in October 31, 1934. Employment began to pick up rapidly in late September of this year, and on October 31 was equal to the figure for January 15, two and a half months ahead.

Production for October was 25 per cent ahead of October a year ago. All manufacturers look to a better year. They plan, however, to extend production over a greater period of time. General Motors Corporation, for example, has announced a fund of $60,000,000 to be set aside for inventories of parts stock that can be safely built up before the peak of spring sales.

As a result, it is expected that the annual earnings of automotive workers will be substantially increased. The real key to the situation, on the other hand, is whether or not the public will actually buy automobiles during the winter months.



PRODUCTION INSPECTOR'S REPORT ON GLASS QUALITY

FOREMAN: Shift No._____ Date_____ 19____

No. Mach.	General Condition of Sheets	DEFECTS AND ESTIMATED % OF EACH									Time Defects Reported	Time Improvement Noticed	Breakage Estimated Time and Amount Lost	Special
		Waves	Lines	Warps	Dirt and Kind	Seeds	Blisters	Stones	Hot Streak, Etc.	Other				
1														
2														
12														

GENERAL REMARKS:

Signed:_____ Production Inspector

Quality Under the Thumb

This inspector has only to switch on a light or pick up a speaking tube to tell a machine operator what's wrong

J. GAVIN CALLINAN
Industrial Consultant, Columbus, Ohio

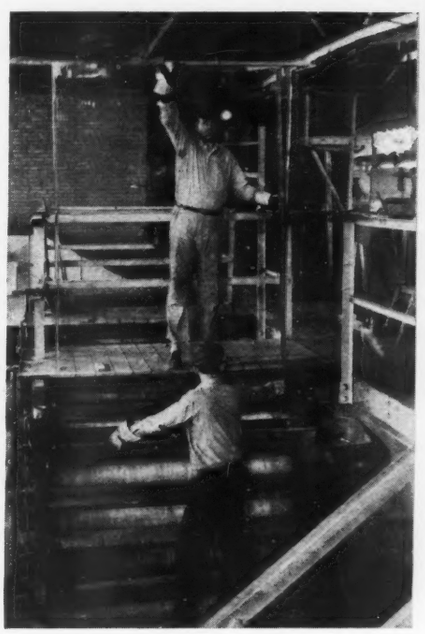
QUALITY in the production department of a flat-glass factory is a variable. Quality in the sales department is a fixed thing rigidly set by government and competitive standards. Only inspection—and then more inspection—can make the various qualities constant in their values and the company's brand one that can be depended upon.

In one plant employing the Fourcault process, the first inspection is made just as the sheet of glass emerges from the top of the vertical drawing machine. In this, the cutting-off department, the foreman and an independent inspector are held responsible.

Foreman Shares Responsibility

The foreman—or checker, as he is called because of his duties in connection with the labor of his department—cannot devote enough time to make a thorough inspection of all the values that enter into quality. He is responsible for the recording and immediate reporting of such things as speed of production, correctness and uniformity of thickness of sheets, breakage and loss due to it. Every 30 minutes he must drop a brief report to the chief operator downstairs. Then, to make certain that the chief operator gives this the attention it deserves, he must copy it on a summary sheet, and at the same time read and record certain operating temperatures.

The real task, however, falls upon the shoulders of the production inspector. The report he fills out every shift is shown in the figure and is placed upon the general manager's desk every morning. Notice that the time interval between the discovery and remedying of defects is recorded. This is a real incentive in getting results from the machine operators.



First inspection is made as glass emerges from vertical drawing machine

What operator wouldn't fight to put out a light that publicizes his deficiencies?

The production inspector has two duties. They are, first, to report defects to the machine operators; sec-

(Continued on advertising page 46)

We Ran a Motion-Study School

And now our foremen all talk the same language, think in terms of motion, can understand one another's problems

C. W. PUNTON
Factory Superintendent
Mine Safety Appliances Company
Pittsburgh

OUR PRODUCTS are used in emergencies when lives hang in the balance. They must function properly, often under adverse conditions, and this means that they must be soundly built. Foremen, production men, inspectors—all the supervisors—must do their work intelligently. There can be no cutting of corners, no relaxing of attention.

With the spirit of seeking to improve ourselves, we have in the past taken various courses, and have discussed pertinent matters in group meetings. One course dealt with foremen's problems—handling men, interpreting company policies, and so on. At another time, we held a series of meetings at which the pamphlets of the National Safety Council were discussed. For four months, weekly meetings were held at which plant problems were considered, particularly from the standpoint of quality and safety.

Shop Men Wanted Facts

Recently it became apparent that what we needed was a course of study that would coordinate our educational activities and give our meetings a definite objective. We had definite specifications in mind. The course must deal with operating methods from the modern motion-study viewpoint. It must deal with our own problems, not with theory. Finally, meetings must be conducted by a good leader with a practical viewpoint. Our shop men wanted facts and everyday applications, not abstractions.

It looked as if the course in motion and time study offered by the Methods Engineering Council of Pittsburgh would give us what we wanted. Arrangements were accordingly made to have the course given in our plant, and certain key supervisors were selected to take it.

It was clearly explained to all concerned that the purpose of the course was to give an understanding of the methods, practices, and viewpoint of the methods engineer, and a knowledge of the principles and techniques he employs. The purpose was not so much to make motion-study men out of all the supervisors as it was to enable them to cooperate intelligently with the methods engineer and to

Outline of Methods Engineering Course for Supervisors and Foremen

I

History and development of methods engineering. Economic and social aspects of work of methods engineer. General illustrated outline of the techniques employed by the methods engineer, including job analysis, stopwatch time study, motion study, motion-time determination, plant and workplace layouts, related subjects

II

Job analysis. Analysis sheet. What to look for. Motion pictures. Preliminary analysis of operations on major group project. Discussion of analysis sheets made out by group. Flow process charts. Application of chart. Introduction to stopwatch time study

III

Elements of time study. Practical shop psychology for conducting time-study work. Time-study observations. Working up a time study. Discussion of skill and effort. Leveling principle. Group experiments to illustrate theory of leveling and correctness of performance rating factors. Allowances. Fatigue, personal, special, and unavoidable delay allowances. Computing allowed time. Formulas for determining most efficient machine or set-up

IV

Basic divisions of accomplishment. Definitions and explanations. Efficient and inefficient basic divisions. Methods of making improvements as the result of recognizing and listing basic divisions of accomplishment. Operation process charts. Five laws of motion economy and their eight corollaries. Explanation and discussion of laws and corollaries. Application to major group project

V

Characteristics of motions. Five classes of motions the human body can make. Characteristics of five classes of motions. Group experiments with motion-time determination. Predetermined motion-time standards. Factors of "Plan" and "Control." Practical applications of knowledge of motion times and applications to workplace layouts. Film analysis procedure. Frame-by-frame analysis of several operations of the major project. Program for further improvements. Assignment of individual projects for thorough methods study

VI

Man-and-machine charts. Plant layout practices. Conveyor systems and machine coupling. Procedure for operator training. General aspects of leading wage incentive systems. Group work. Uses of time allowances as (a) supervisory aid, (b) methods engineering department aid, (c) production and planning aid, (d) accounting department aid. Administering an incentive plan. Time formulas

instill in them a keen desire for efficient operating methods.

Meetings were a success from the start, and supervisors were eager to attend. We tried to select a limited representative group to take the course, but found that practically all the supervisors wanted to be included. The group was finally composed of the general foreman, all department foremen, safety director, tool designer, two men from the accounting department, plant methods engineer, assistant production manager, stores order man, an inspector, and several subforemen and group leaders.

The course consisted of fifteen discussion periods of approximately two hours each. It covered the subjects listed in the accompanying outline. From time to time we took motion pictures of some of our operations and applied to them the principles we were studying. If we needed samples of the parts to experiment with, we were able to get them from the shop in a few minutes. To give coherence to our work, we chose as a major project an active job on which some twelve operations were performed. This job formed the basis of our application discussions. Many improvements were made on it before we finished. Ultimately we expect to effect a 50 per cent reduction of time on the job as a whole.

Methods Man Was Swamped

Beneficial results were felt almost from the start. The supervisors began to think about jobs in terms of motion and began to improve setups. Before long the plant methods engineer was swamped with requests to make time studies on the jobs they had improved.

One interesting point about the course was that it meant different things to the different men taking it. The foreman of the shipping and finished stores department, for example, received the greatest benefit from the discussions of process charts and plant layouts. He applied the information and as a result was able to save the time of three men at a period when his department was getting increasingly busy.

The foreman of the first aid department, on the other hand, found the principles of micromotion study particularly applicable to his work. He applied them to some of the more active jobs and found that he was able to improve methods on operations which he had long felt to be inefficient without being able to do anything corrective about it.

Safety, of course, is one factor on which we place great stress. Our safety director was delighted to find that the application of motion study, instead of causing workers to speed up and work dangerously, actually increased safety. He found that efficient methods are safe methods.

One nice thing about a course in motion study is that results begin to show right away. On the two following pages are "before" and "after" pictures of jobs that were improved as foremen began to think of the task at hand in terms of motion

The production man found the information about time standards useful as a basis for his planning activities. The accounting department men received a better understanding of shop practices, which helped them in their cost work. The stores order man got a better insight into the effect of quantities on costs and methods, and thus was able to improve his system of placing orders for stock items.

Savings Offset Cost

Improvements of the sort illustrated by the photographs on the following pages brought savings that offset the cost of the program many times. Even more important from a long-range viewpoint is the better understanding our key supervisors have gained of one another's problems. Each foreman realizes the problems faced by other foremen; the foremen appreciate the viewpoint of the plant methods engineer; the production men see the problems connected with the ordering, storing, and shipping of goods; and the accounting department realizes more clearly what goes on in the shop. All supervisors talk the same language, because they have the same basic understanding of what constitutes efficient performance.

Although we have already accomplished much, we feel that we are going to do still more in the future. A wave of rush work toward the end of the course meant day-and-night activity for most of us. Consequently several of the projects on which we were working were not completed by the time the course ended. The supervisors have made it a point of honor among themselves to finish these projects as soon as time permits.

Job Is Barely Started

Later on we plan to go into methods work more deeply. Although this is only one phase of industrial management, it appears to be the foundation for many, if not most, manufacturing problems. Correct methods mean economical manufacturing costs, high quality of product, and safe working practices. Methods that eliminate waste permit quicker delivery schedules. Personnel problems are lessened because good methods reduce fatigue and make the work more pleasant for the operators. Sound wage practices increase the workman's economic satisfactions. Methods work will also make it easier for us to train new operators and will reduce the length of the training period.

Our experience thus far has indicated that one meeting a week for fifteen weeks was not sufficient to discuss methods problems as thoroughly as we should. Interest in methods work was maintained throughout the course, and is at the present time even keener than at the start. Some of the supervisors have taken up advanced courses. Others have asked that we continue the course, taking up such subjects as planning, routing and scheduling, and production problems, as well as making additional group methods studies on the more important jobs. This we hope to do, for we are convinced that the benefits we have received thus far are but a part of those we may expect to obtain as our knowledge of methods engineering principles and practices increases.

Before Motion Study . . .

Samples of better methods instituted by foremen at Mine Safety Appliances Company, Pittsburgh

1 Corner of shipping department before methods study. Material placed in bins from front by storeroom attendants. Packing, weighing, insuring, marking, and stamping all done in approximately same space

3 Soldering terminals to lamp cables before methods study. Terminal held in left hand. Soldering done with iron held in right hand. Solder obtained from shallow pan in front of operator

5 Inserting iodine swab in cardboard tube container before methods study. Swab placed by right hand in tube held in left hand. Left hand holds while right hand gets other half of container. Assembly tossed aside in box on bench

and After

DETAILED ACCOUNT *of the course in methods engineering given for foremen at Mine Safety Appliances Company may be found in the article by C. W. Punton, Factory Superintendent, beginning on page 510*

2 Corner of shipping department after methods study. Material placed in bins from rear by storeroom attendants, thus keeping trucks out of packing area. Packing and weighing done on one side of bench; marking, insuring, and stamping on other. Empty carton supply moved nearer packers. 30 per cent more production

4 Soldering terminals to lamp cables after methods study. Terminals held in wooden fixture made by foreman. Soldering iron held in right hand and wire solder in left. Production increased from 185 to 400 per hour

6 Inserting iodine swab in cardboard tube container after methods study. Swabs placed in sheet metal container as they are laid aside on previous operation. Container is set on wooden holding fixture. Swabs roll to assembly position. Both hands move simultaneously assembling swab in container. Assembly released by drop delivery through hole in bench. Production increased 33 per cent

You Want to Know

. . . and the editors will gladly tell you . . . more about the things mentioned on this page

• PLIERS, rustproofed, come in sets of four, each designed for different type of work. (12503)

• DIRECT-LOANS guide, a booklet you can get, deals with ways and means of obtaining RFC, Federal Reserve, FHA loans. (12504)

• PAINT FILTER for spray booths retards discharge of sticky residue into exhaust chamber or pipe. Only solvents, thinners, or dyes will go through it. Solids may be reclaimed. (12505)

Motion economy enthusiasts, methods men, and anyone else who makes motion-cycle charts will want a set of "Therblig pencils." Color and symbol to use for each type of motion are plainly marked on container. (12501)

• VALVE with micrometer-setting indicator controls flow to 1/100 of a turn of the handwheel. For processes where accurate valve settings are necessary and must be duplicated exactly. (12506)

• SOCIAL SECURITY facts in question and answer form are available for distribution to employees. Booklet tells worker all he needs to know about pension and unemployment compensation plans. (12507)

• GLASS WOOL, originally developed for insulation, has now been refined into fibers that can be carded, spun, and woven. (12508)

• VENTILATED buff is self-cooling, eliminates flying lint, reduces smoke and fire hazards, permits high surface speeds, combines savings in compounds with greater output. (12509)

• ZINC die castings—two free booklets. One, with 144 photographs, pictures complete scope of die-casting applications; other is a research bulletin on four die-casting alloys, contains valuable technical data for design engineers. (12510)

• LUBRICATION engineering — a non-profit institution offers correspondence course, announces handbook for technical men. (12511)

• FINISHING process, newly announced, produces cellulose nitrate coating on metal, wood, rubber, glass, etc. Variety of decorative effects may be obtained. Sponsors claim high mechanical strength and resistance to wear, weather, chemical influences. (12512)

• SLEET or snow on windshields is effectively melted by a non-electrical gadget that uses the same heating principle employed in chemical heating pads and elsewhere. (12513)

• FLEXIBLE-SHAFT tool for precision work on wood or metal may be pre-positioned above workbench, thus leaving hands free to handle the work. Speed range, 1,700 to 12,000 r.p.m. Delivers ¼ hp. at any speed. (12514)

• DIESEL questions are answered in a non-technical booklet that gives a lot of basic whys and hows before it settles down to straight sales promotion. (12515)

• RUSTPROOFING at low cost is promised by a process that changes the surface instead of coating it with a layer of phosphates. Said to afford a protection that will not break or cause paint failure when product is bent or distorted. (12516)

• FIRST-AID kit consists of two steel cases. Outer is permanently attached to wall; inner contains 10 first-aid units, each holding enough material for several treatments. (12517)

• FILING CABINET, metal, has (1) receding base to allow for toe room, (2) continuous tubular handles to facilitate opening, (3) index cards on top drawer where file clerk can read 'em. (12518)

• AIR CONDITIONING — unusually attractive booklet tells why for home and office. (12519)

• LOOSENS scale by electronic action, prevents new from forming in tanks where water is heated—all done by a glass container that holds three inert gases and treated mercury, stands 400 deg. F. and 1,000 lb. pressure. (12520)

• TELESCOPING towers, mostly aluminum, afford safety-first method of approaching high-up dirt. (12521)

• MARKET DATA on industrial products—a free booklet charts major markets for tools, equipment, and supplies (130 items) ordinarily sold through distributors. (12522)

• TELEPHONE, wall-mounted handset type, permits one-handed operation, leaving other free to take notes, etc. For noisy locations, there's an anti-noise variety. (12523)

• REDESIGNED in aluminum, a portable warp-tying machine weighs 290 lb. less than it used to. (12524)

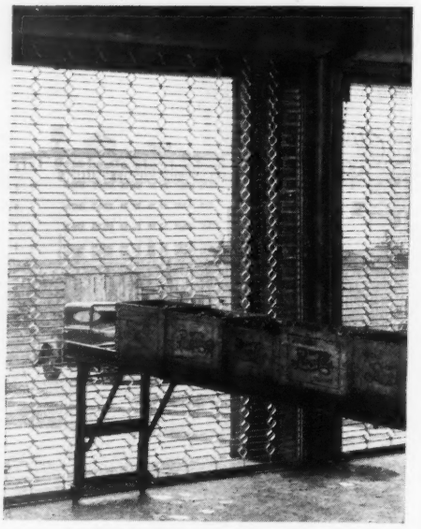
• PAPERS finished to look like lebanon cedar, mahogany, etc., are on the market. (12525)

• BOLT CLIPPER has swivel head which enables user to reach hard-to-get-at bolts. (12526)

• THERE'S a concern that specializes in cartons and packages for hard-to-pack products. (12527)

• BUILDING BLOCKS—those glass ones that let in light but can't be seen through—are now enameled and sanded on sides so the mortar will bond more effectively. (12528)

• PACKAGING prize for the month goes to the French concern that compresses tooth powder into a cake, plastics-packs it. (12529)



For the shipping platform there's a protective rolling grille that can be quickly raised or lowered. Small opening in center permits loading while grille is down. (12502)

To Keep Small A.C. Motors Going

Ruggedness of induction motors cannot overcome handicaps of improper installation and neglect of bearings, windings, other parts

E. C. DIEFFENBACH
Industrial Department, General Electric Company
Schenectady, N. Y.

BEFORE leaving the factory, motors are subjected to rigid inspections and tests for mechanical and electrical fitness. These inspections and tests have been standardized; all reputable electrical manufacturers make them before a motor is considered ready for shipment.

Before the Juice Is Turned On

After installation in the plant, the following checks should be made before power is applied:

1. Insulation resistance
2. Motor connections
3. Control connections
4. Fuse sizes
5. Bearings
6. Freedom of rotor

Insulation resistance tests are hardly necessary where the motor has not been in transit very long. When the motor has been in a warehouse or has been idle for a time before installation, this test should be conducted to make certain that moisture has not been absorbed in sufficient quantity to weaken the insulation between phases or to ground. At the operating temperature of the motor (40 deg. C. rise for standard motors designed for continuous operation) insulation resistance readings should not be lower than the values given by substituting in the formula:

$$\textit{Resistance in Megohms} = \textit{Rated Voltage} \div (\textit{Kva. Rating} + 1{,}000)$$

Connections to the power supply should be checked with the connection plate on the stator. If the motor can be connected for different voltages, such as 115/230 or 230/460 volts, be sure that the proper connection has been made for the voltage supplied.

Control connections should be checked with the connection diagram furnished with the control apparatus.

Proper maintenance means fewer trips to the repair shop

Fuse sizes must comply with the regulations laid down in Section 808 of the National Electrical Code.

Bearings should be filled according to instructions. Fill sleeve bearings with a good grade of motor oil (oil companies can supply a mineral oil of S.A.E. viscosity No. 20). Ball bearings should not be overfilled with grease, because they may overheat and excess grease may find its way into the windings. As received from the factory, new motors have the proper quantity of grease in the bearings. Under normal conditions they do not require further attention and are ready for operation.

The rotor should turn freely by hand. This test will indicate that static friction is low and that the motor is properly aligned.

Maintenance Is Responsible

A well-organized electrical maintenance department has a definite routine and its own system for keeping records of individual motors and other electrical apparatus. How the routine is worked out, depends upon many factors such as size of plant, type of service (continuous or intermittent), atmospheres encountered (dusty, moist, explosive, abrasive), ratings of motors (physical size), ambient temperatures encountered, voltages, and so on. Some plants maintain their own electrical repair shop and do their own work from cleaning and testing to rewinding, dipping, and baking. Other plants only inspect and service the electrical apparatus, leaving the repair work to commercial repair shops.

In either event, after a motor is in operation, the maintenance department is responsible for the items enumerated below. Some of these items were mentioned previously, but they require regular attention during the operating life of the motor, if the best results are to be expected:

1. Insulation
2. Condensation
3. Bearings

4. Air gap
5. End play
6. Collector rings and brushes
7. Frames

Insulation on windings should be kept clean to permit the heat dissipation for which the windings were designed and to minimize the possibility of leakage paths to ground. Cleaning is done by applying dry compressed air at a pressure not to exceed 40 lb. per sq. in., and using a small brush.

Carbon tetrachloride is an excellent solvent for removing dirt which cannot be blown off. When this solvent is applied sparingly with a cloth and a wooden scraper is used, encrustations can readily be removed. If used too freely, however, it may impair the insulation itself since it is also a solvent of insulating compounds.

After cleaning, windings should be well dried under good ventilation before returning to service or before spraying or dipping with new insulating compound. If the plant has facilities for applying insulating compound and baking, the windings should occasionally be dipped and baked in a controlled temperature of not over 90 deg. C. until dry. Windings of larger motors that cannot readily be placed in ovens may be dipped in air-drying insulating compound.

Keep Windings Dry

Moisture on the insulation of a motor, when no external cause is apparent, is usually attributed to condensation. After a motor has been shut down it cools to the ambient room temperature. If the ambient temperature should rise quickly, the windings, frame, and other parts will be relatively cooler and condensation of atmospheric moisture may occur.

In damp locations the remedy is to keep the windings warm while the motor is idle by applying a current of low voltage or, externally, by means of unit heaters. If the motor is inclosed in a tarpaulin, leaving an opening near the top, and unit heaters are placed near the bottom of the space, the heat will be directed effectively through the windings.

If moisture is found in a totally inclosed motor, it may be due to actual leakage through the machined fits at the end shields or bearings, or to condensation. Sealing the fits with Glyptal No. 120 when the motor is being assembled is an excellent precaution. Holes $\frac{3}{8}$ to $\frac{3}{4}$ in. in diameter drilled into the case and fitted with plugs may be provided for draining. An optional arrangement is to supply pipe extensions instead of plugs.

Totally inclosed motors bearing the labels of the Underwriters' Laboratories attesting their suitability for operation in hazardous locations should *never* be provided with holes for drainage.

A bearing that receives the proper attention is neither over- nor under-oiled. Under-oiling invites wear, noise, and eventually an impaired air gap. Over-oiling causes an accumulation of excess oil on the windings, which in turn collects dust, lint, and other deposits.

Ring-oiled bearings have large oil reservoirs, but when in operation for long periods of time without attention the oil level may become so low that accumulated sediment and sludge may not have an opportunity to settle properly. It is advisable to renew the oil occasionally to within $\frac{1}{8}$ in. of the top of the gage.

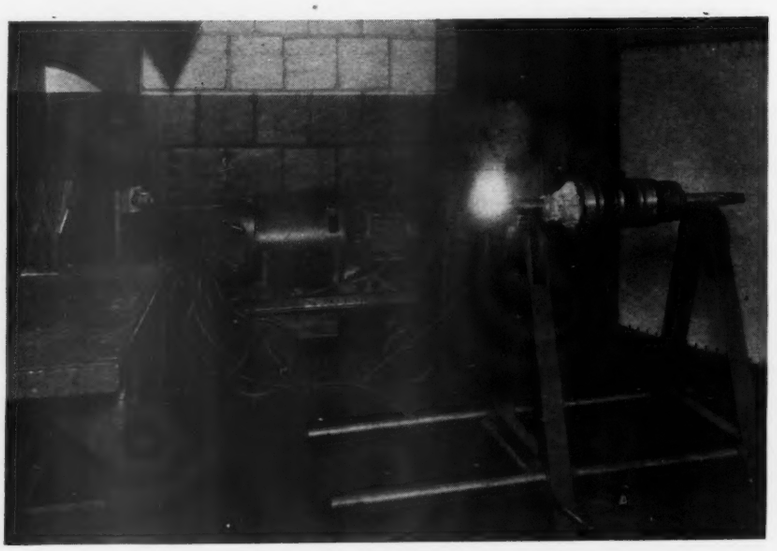
When disassembling the motor for general reconditioning, it is well to flush out the housings and bearings with carbon tetrachloride. Care should be taken to dry out all the solvent before again filling with oil.

Waste-packed bearings require occasional repacking of the waste to renew the oil-storing capacity. When giving a motor a general overhauling, it is advisable to remove the waste and flush the reservoir and sleeve bearing thoroughly with a light flushing oil or with carbon tetrachloride. Repack with new waste if the old material is too worn or matted.

In caring for grease-lubricated bearings, particularly the ball or roller type, the tendency is to overfill the bearing. An overfilled bearing may run hot until the excess grease has worked out, to accumulate on the windings, frame, or floor.

Watch Bearings and Air Gaps

Grease-lubricated bearings may be cleaned by flushing with hot, light mineral oil or carbon tetrachloride if the inclination of the motor shaft does not exceed 15 deg. from the horizontal. If the solvent used is carbon tetrachloride, the bearing should be flushed with light mineral oil to remove all traces of solvent in pockets or recesses. New grease should then be supplied through the pressure fitting. If the bearing is not equipped with a pressure fitting, it will have to be disassembled to clean and refill.



Worn shafts can easily be built up by welding

The air gap, as measured with the tapered air gap gage, should not be less than 0.008 in. for motors of 1 to 3 hp., and 0.014 in. for motors up to 75 hp. In motors rated more than 75 hp., the air gap should not be less than 0.020 in. If it is less than these values, replace the bearing linings.

(Continued on advertising page 50)

More Light for Assembly

Use of high-intensity mercury vapor lamps in combination with Mazda units eliminates local lights when assembling machine tools

ROGER HEALD
President, The Heald Machine Company
Worcester, Mass.

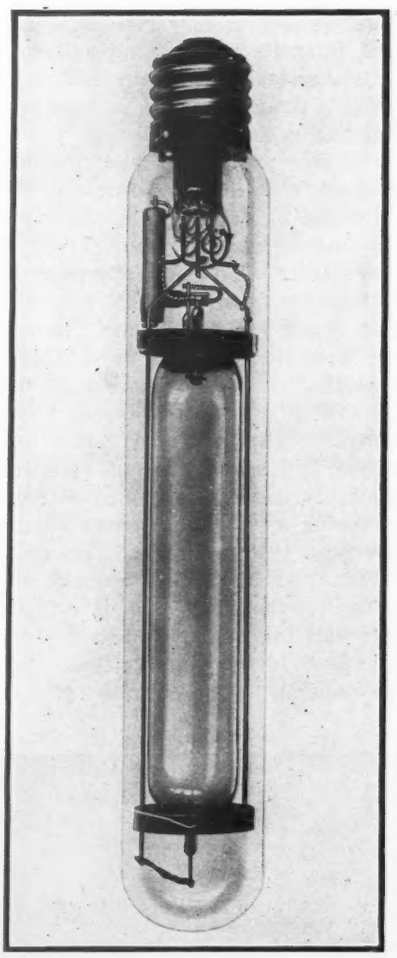
ESTABLISHING the conditions necessary for precision work on a piece of equipment weighing a pound or so is one thing; establishing similar conditions for equipment weighing four or five tons is quite another. Nevertheless, in the construction of our automatic grinding and boring machines the size and immobility of the units cannot be allowed to provide an excuse for departure from workbench standards.

In carrying out assembly and inspection operations on such large, heavy equipment with a necessarily intricate arrangement of parts, lighting that will provide workbench standards of visibility at all points is a primary necessity if precision standards are to be maintained. In fact, the demands upon the lighting equipment under such conditions are even more rigorous than on a workbench, since a 5-ton machine cannot be tilted or moved toward the light source when an objectionable shadow falls across a point on the working surface.

Until a few months ago we were convinced that adequate illumination at all points for assembly of these machines lay beyond the possibilities of fixed overhead lighting, except at a prohibitive expense for current. Consequently our overhead lighting system was based on the use of auxiliary drop lamps and hand lamps where and as needed by the individual worker or inspector.

7 Foot-Candles Not Enough

The section of the plant where this work was carried on is of sawtooth construction, 20 ft. high, with columns on 20-ft. centers. Overhead lighting in each bay formerly consisted of four 100-watt lamps in RLM reflectors on 10-ft. centers, 12 ft. high, operating from a 110-volt line. Lightmeter tests revealed that overhead lighting produced approximately 7 foot-candles illumination at the usual working level.



Standard high-intensity mercury vapor lamp, rated 400 watts

Illumination on the assembly floor is provided by four 100-watt Mazda units in each bay, mounted on 10-ft. centers, 12 ft. high, and one 400-watt high-intensity mercury vapor lamp located in the center of the bay, 17 ft. from the floor. Addition of the mercury vapor units increased the intensity from 7 to 30 foot-candles

Although adequate for general illumination, this intensity was obviously below the level required to provide efficient working conditions without hand lamps, particularly in restricted spaces cut off from direct light by other parts of the machine or by the shadow of the workmen themselves.

Use of drop lamps and hand lamps,

although necessary under the conditions then existing, was recognized as objectionable both from the standpoint of maintenance expense and of delay and inconvenience of having to shift them from place to place. Moreover, it was apparent that good visibility was still secured only at certain times and in certain places.

A Way Out Was Found

When it was suggested that both visibility and working convenience could be increased by installation of high-intensity mercury vapor lamps, several serious doubts and objections arose. Granting that a high-bay lighting system of this type would be more convenient and provide greater visibility, we foresaw the necessity of scrapping our present lighting equipment, undertaking a complicated wiring job, and possibly ending up with prohibitive power bills if any real improvement in seeing conditions was to be obtained. Consultation with engineers of the General Electric Vapor Lamp Company, however, revealed that a balanced lighting system of excellent visibility could be obtained without changing a wire or a fixture of the overhead system then in operation.

The plan as finally worked out called for the installation of a single 400-watt high-intensity mercury vapor lamp in the center of each bay, mounted in an appropriate reflector 17 ft. from the floor. These lamps are the new type that are screwed vertically into a regular Mogul socket beneath reflectors quite similar to those for regular Mazda service.

Units of this type were installed and independently wired to the 220-volt line without interference with plant operation. The existing Mazda installation was left intact, to be used along with the mercury vapor lamps. This arrangement, although perhaps not so efficient as mercury vapor lamps alone on a straight lumens-per-watt basis, provides a more flexible system and made it unnecessary to scrap any of the existing equipment.

Four Times as Much Light

Power consumption of each mercury vapor lamp rated at 400 watts is about equal to that of the four 100-watt Mazdas in each bay. After their installation, however, it was found that illumination at the working level had been increased from 7 foot-candles to more than 30 foot-candles, with both sets of lights in operation. This fourfold increase in general illumination has enabled us to discard the use of hand lamps almost entirely, the consequent saving in maintenance expense going a long way to offset the extra 400 watts per bay now used.

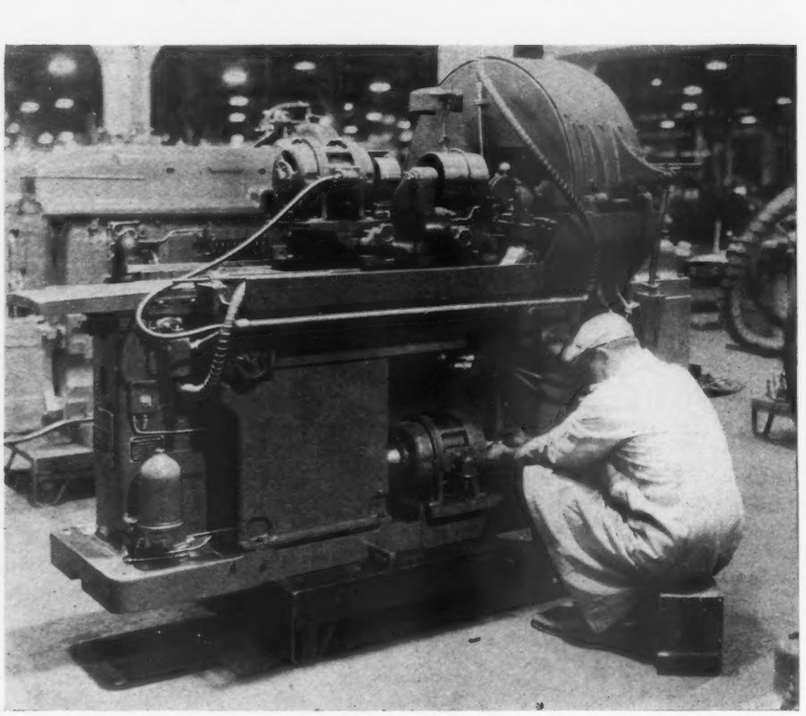
The quality of the light itself and its effect upon the assembly operations are matters difficult to discuss objectively. I feel, however, that we have secured an improvement in production efficiency since the installation of the new system that amply justifies the step. Whether this improvement in efficiency is due directly to the increased illumination, to the particular quality of the light in providing high visibility, or indirectly to the elimination of eye fatigue and its effect upon morale, or to some balance of the three, I am not qualified to say.

There is one point, though, upon which reactions are perhaps not out of place. Many individuals, I know, have always objected to the lack of red in the ordinary mercury vapor lamp installations, which results in unnatural appearance of the skin and colored objects. Although this unnatural color effect may be better from an abstract visibility standpoint, its psychological effect on operators who have been accustomed to working under incandescent light may be quite the opposite.

They All Like It

To a large extent this possibility is offset by the fact that the high-intensity mercury vapor lamps give a considerably whiter appearance than the standard Cooper Hewitt type of tube. Moreover, by continuing the Mazda lamps in service, enough of the red end of the spectrum was added to produce light of natural appearance as well as excellent visibility. We did not have to "sell" a single workman on the fact that the new lighting system was better for him, since the personal reactions of the men coincided with our own judgment.

At other points in our plant we are now using Mazda lamps alone and Cooper Hewitt tubes alone. It certainly does not take a lighting expert to see that the new system installed for assembly and inspection is the outstanding example of the lot.



With the new lighting installation there is no need to use the drop lights formerly necessary for assembly

. . . up to his knees in water digging a trench

He Was a Workin' Fool

Mike gets big returns on a regular investment in cooperation—all to the good for the plant

D. W. ROBERTS
Mechanical and Electrical Engineer
Chicago

MIKE carried the map of Ireland on his face. He hadn't been in this country long; his wife was still in the old country. Mike was a helper in the gang that built substations, installed powerhouse equipment, pulled underground cable, and maintained the heavy electrical equipment.

I was looking for a man to put on as night maintenance electrician in a group of buildings including an all-night metallurgical process. It was the dirtiest location in the plant. The hours were long.

Mike was recommended by two foremen. He had no maintenance experience, but had quickly learned to read a blueprint when assigned to help a switchboard wireman; he had helped to dismantle motors; he was mature, and the better pay would help him bring his family over.

You Must Have Friends

"Mike," I said, "I hesitate to put you over there, but your foreman says you can do it, and your new foreman is willing to give you a chance. Now I know that you will meet plenty of trouble you don't know anything about. You must have friends or there is no hope for you."

"Yis, sorr, I know," said Mike.

"Well, Mike, I can give you a little advice. There will be an elderly man on the same shift with you. He is a millwright, but he knows more about the electrician's trade than you may know when you die. He would be a good friend to have."

"That he would, sorr."

"The night-watch engineers know quite a lot about electrical matters, and if you have bearing trouble, particularly, they might be helpful."

"Yis, sorr, I know."

"Now one more thing, Mike. You can't have delays on your shift, and you can't drag your foreman out at night every time something puzzles you. Try not to call him except on big breakdowns."

"Yis, sorr, I know."

A few months later I was over Mike's way and followed the trail of a veritable flood into a building. I found Mike up to his knees in water digging a trench and breaking up the concrete floor as he went along.

"What's your trouble, Mike?"

"No trouble of mine at all, sorr. The steam fitter says it's a break under the floor on the way to the sprinkler valve. He's gone over to get a sleeve and a bit of pipe, and I thought it would do no harm if I uncovered the pipe a bit while he's gone. He'll be gone some time, I'm thinking, because there is snow over the yard where the pipe is stored."

He'd Get Along, for a Fact

"Did you ever see a man pour a lead joint, Mike? You must have less water in that trench before you can pour lead, even if you use kerosene behind the roll of clay."

"That's what I've been thinking, sorr."

"What would you think of the pump your old gang used to pump out manholes with? Here is the key to the vault where it is stored. By the way, Mike, what is happening to your motors? You'll be here the rest of the night at this rate."

"That I will, sorr, but the millwright said he would make rounds for me, sorr, as he went around looking after his own stuff. I did all the climbing for him in erecting that structure he had to put up nights for the fans. He's an old man, sorr, and has a bad knee.

"Now, if you don't mind, sorr, I'll call up the electrician on the other side and ask him to go and get me the pump. He'll do it, sorr. I worked in for him last Christmas eve. I was off and have no family in this country, sorr, and he has little children. He has helped me out before when I was a bit puzzled on a clapper board starter, sorr."

He would find a way for a fact. Mike would get along. I was sure of it when I told the watch engineer where Mike was and asked him to send word if any trouble calls came in.

"He's a workin' fool," said the engineer. "He fired a relay boiler for me one night when a fireman got cramps. It took me two hours to get a day man out, but Mike didn't lose the steam; said he had watched to see how it was done many a time. He has nothing but friends around here."

Synchronous Motor Field Control

Application of direct-current field at exactly the right time improves starting, may increase pull-in torque 30 per cent

C. W. DRAKE
Industrial Division
Westinghouse Electric & Manufacturing Company
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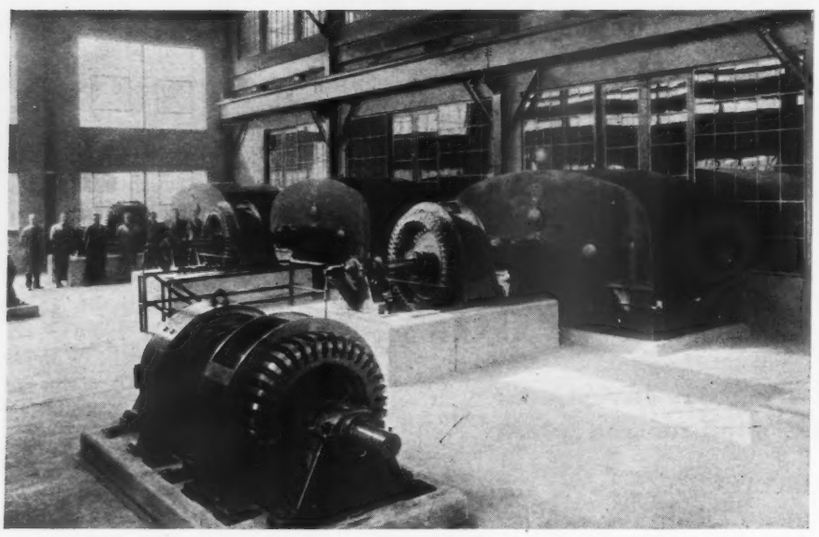


Control for these synchronous motors driving tube mills includes angle switching of the d.c. field

DURING recent years numerous improvements in the starting, accelerating, and pull-in characteristics of synchronous motors, together with standardization and simplification of the control equipment, have so expanded the field for synchronous motors that they may now be used for practically all constant-speed drives. Until synchronous speed is reached, however, synchronous motors operate as induction machines; hence there is the same opportunity for a variety of speed-torque characteristics as with induction motors, and numerous modifications have been developed to meet load requirements.

Certain characteristics are desired for compressors, pumps, and fan drives; other, and entirely different, characteristics are needed for line-shafts, rock crushers, and miscellaneous industrial applications. Some of these speed-torque characteristics are shown in Figure 1. Always there is a point where the motor must change from the induction to the synchronous characteristic when the d.c. excitation is applied, and the rotor must reach the speed of the primary rotating field and run in exact synchronism with it. This is known as the point of pull-in. The torque developed at this point or speed is often a determining factor in the choice of a motor for a certain application.

Determining Pull-In Torque

For purposes of comparison and definition, the pull-in torque has been commonly agreed upon as that developed by the motor at a certain per cent slip or speed and the torque as a certain percentage of the full-load torque. The speed to which a motor will bring its load depends upon the power required. Whether the motor can pull the load in step from this speed, depends upon the inertia of the revolving parts; so the pull-in torque cannot be determined without knowing the WR^2 of the external load as well as the torque of the load. A motor speed of 95 per cent of synchronous speed has commonly been agreed upon as a basis of comparing pull-in torques, although with high-inertia loads, large centrifugal pumps, blowers, and so on, the motor must often operate at a higher speed in order to pull the load in synchronism.

Pulling Up to Speed

An accurate description of just what goes on at this critical point would be highly technical, but it is readily seen that the characteristics of the load have a very important bearing on the ability of the motor to accelerate quickly from its slip speed to its synchronous characteristic. It has long been known that when the d.c. excitation is applied the motor sometimes pulls into step very smoothly and with little line disturbance, whereas at other times

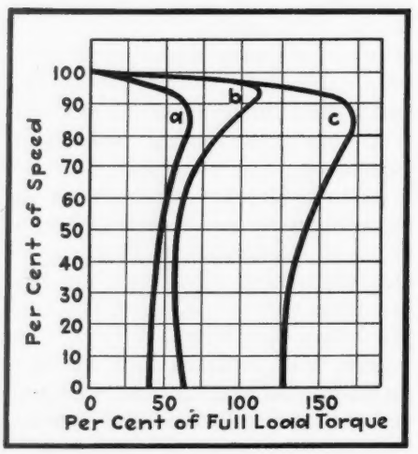


Figure 1. Speed-torque curves of synchronous motors during starting. Characteristics shown by curve *A* are suitable for air compressors and other machines with unloading devices; *B*, suitable for pumps, blowers, etc., that require full load at rated speed, but impose low starting torque; *C*, necessary for many industrial drives that have a high friction load at start and impose rated load at synchronous speed

there is considerable oscillation of the meters before the motor settles down to a steady load. It was known that this difference in the operation was due to the relative positions of the field poles and the stator when the excitation was applied, but if the motors pulled in satisfactorily each time, there was little cause to worry about the way it was accomplished.

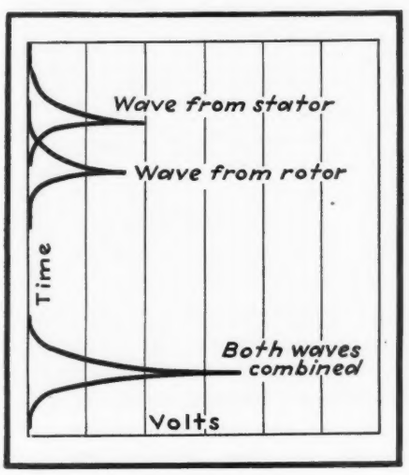
Torque Tests

Tests have recently been conducted on synchronous motors up to 900-hp. capacity, and, besides oscillographic records, special equipment was designed for recording the rapidly varying torque developed during the transition stage. When applying the field voltage in the usual manner, after a definite time or at a definite speed, results indicated, as was expected, that under certain conditions the torque at the motor shaft fluctuated rapidly between quite high positive and negative values before reaching a steady state.

Although of little importance in most instances, it is desirable on some applications to prevent such reversal of torque. One such application involved a 900-hp., 720-r.p.m. synchronous motor driving a cement tube mill through double-reduction gearing. With a tube mill weighing 70 tons or more and having a normal running torque of 250,000 lb.-ft., a reversal of torque during synchronizing might set up severe stresses in the gearing; therefore, it was required that there be no such reversal of torque. To meet this requirement, equipment was developed that would consistently apply the field excitation at the most desirable angular position.

The apparatus consists essentially of a means of checking the position of the rotor against the space position of a particular phase winding at a predetermined point on the wave of voltage impressed across that phase. This feature is in addition to whatever type of starter may be employed, except that, when the usual field switch operates, it energizes the angle switching system instead of applying the field. The angle switching device then applies the excitation voltage to the motor as soon as the rotor and the impressed voltage pass through the predetermined relative position.

Figure 2. When peaked waves from stator coil and inductor generator on rotor shaft coincide, voltage causes electron tube to function



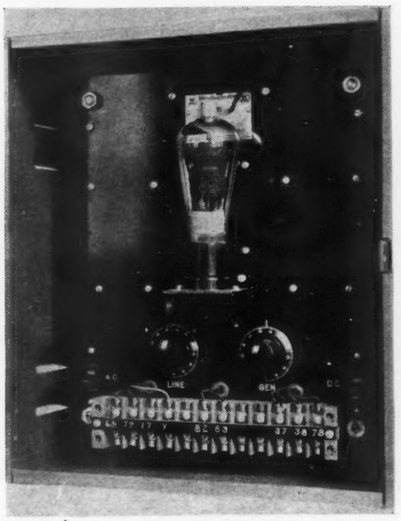


Figure 3. Electron tube panel of auxiliary control for applying d.c. excitation at the proper time

Maximum Primary Voltage

To determine when the voltage impressed on the primary phase coil is at a maximum, a special transformer that produces a peaked wave is connected across it. The rotor position is checked by means of an induction-type generator, whose rotor is mounted on the shaft of the synchronous motor. The stator is supported from a pedestal bearing or bracket, and the magnetic circuit is arranged so that it may be shifted to obtain the desired position of the generated voltage peaks. Such a generator has no rings, brushes, or wearing parts, and maintains its adjustment permanently.

A simple circuit with a grid-glow tube is utilized. When the two peaked voltage waves from the line and from the inductor generator coincide, the tube becomes conducting and operates a high-speed relay which in turn applies the field excitation. Since the tube is energized only during the starting period, its life is extremely long. Figure 2 illustrates the type of waves produced. A view of the grid-glow tube and its panel is shown in Figure 3. On the back of the panel is mounted the small transformer that provides the peaked wave from the primary.

The illustration at the beginning of this article shows an installation consisting of two 800-hp. and two 900-hp. synchronous motors using angle switching equipment for field application. On the shaft extension are magneto speed indicators so that the operator may observe the speed during the starting period. The inductor generators for the angle switching equipment are mounted on the shaft inside of the pedestal bearings. Coupled to each motor is a double-reduction gear unit reducing the speed from 720 to approximately 19 r.p.m. On the other side of the partition are the 8x36-ft. tube mills that are coupled to the low-speed shafts of the gear units.

Synchronizing Equipment

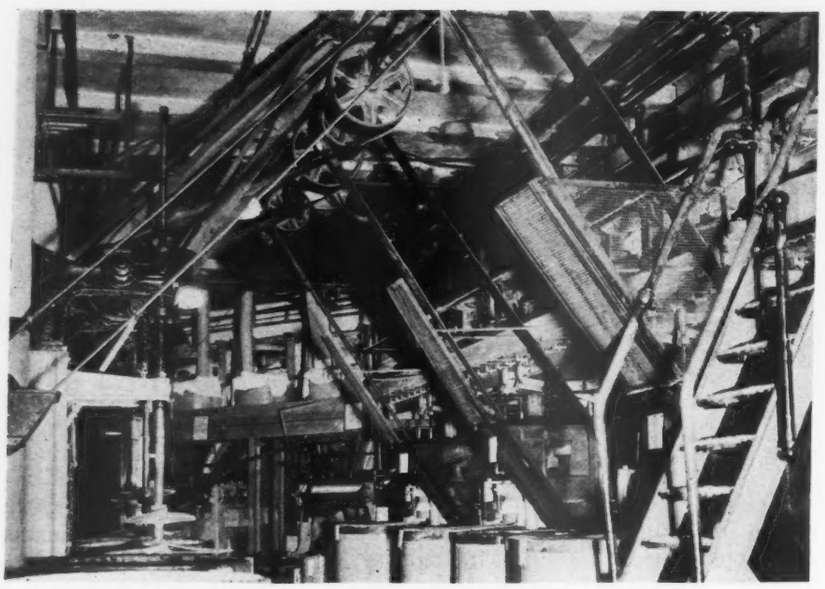
In this installation the angle switching equipment was used to prevent reversal of torque at any time during the synchronizing period. Application of field excitation always under the most favorable conditions makes it possible to utilize or depend upon the maximum synchronizing torque of a motor; otherwise only the average value can be considered. This increase in available torque, which may be as much as 30 per cent, is of considerable importance in many instances.

This method of switching may be used for other purposes. For example, it has been used to synchronize two compressor motors so that they will always operate with the compressor cranks in a predetermined angular position. Such an arrangement prevents overlapping of the current pulsations in the line and might in some cases also be desirable from the standpoint of building vibration.

Repowered for Profit

$18,000 spent in putting power drives on a modern basis and going from generated to purchased power saves $8,000 annually

J. D. GRAYSON
Assistant Treasurer and Cost Accountant
Devoe & Raynolds Company, Inc.
Brooklyn, N. Y.



A silent chain transmits power from the motor to this lineshaft, which drives two batteries of grinding mills

JUST WHERE the new equipment dollar is to be used is an immortal question deserving of the time and attention devoted to answering it. Those who have been thinking constructively about modernization during the past few years have been confronted by aggressive managements with the acid test of getting the utmost returns from expenditures of this sort. Every proposition has been put on a cash-and-carry basis.

All Departments Would Benefit

Circumstances pointed to our power department as being susceptible to improvement, because 71 motors summing up to 582 hp. were providing about two-thirds of the total power required. A corliss engine, rated 350 hp., furnished power for the remaining load. These facts left us on top of the fence; we could not properly generate enough power for the entire load, and we were not using enough power to justify a lower rate from the utility.

Furthermore, this arrangement had the disadvantage that if one mill were required to run overtime the engineer had to stay on duty and all of the idle shafting had to be operated. We believe in group drives, but not in groups comprising one-third of the plant. Another inducement for modernization was the fact that we had just purchased several pieces of very modern equipment which were by their nature direct-drive units, thereby condensing power requirements into fewer mills, with resulting decreased activity of the less up-to-date units.

Our Brooklyn plant is arranged so that the production of oil paints and enamels flows by gravity from raw materials on the fourth floor to cartoned stock in the basement. Process departments include mixing paste, grinding paste, thinning and tinting to liquid consistency, straining or riddling, filling, labeling, and packing. Power is the common denominator of performance in these operations. Hence, all process departments would share any decrease in the cost of power, whereas an improvement in one department alone would benefit only those products that were processed therein.

More Power for Less Money

A table covering the items listed below and showing the current expenses for heat and power, items that would be eliminated, items that would be increased, and proposed changes was drawn up and provided the basis for considering the next important subject — the cost of changing over.

CURRENT DIRECT EXPENSES
- Fireman
- Operating engineer
- Coal passer
- Indirect misc. materials
- Purchased Current—Cost
  —Kw.-hr.
  —Av. cost
- Coal—Cost
  —Tons
  —Per ton
- Water—Cost
  —Cu.ft.
- Insurance—Compensation
  —Flywheel
  —Liability
- Total Direct Expenses

INDIRECT EXPENSES
- Depreciation of equipment
- Rent
- Interest
- Total indirect expense

TOTAL EXPENSES

NET ESTIMATED ANNUAL SAVING

This tabulation showed that an investment of $18,000 would save about $8,000 a year; so that it would be amortized in two and one-quarter years, which was within the limit set by firm policy when considering extraordinary expenditures.

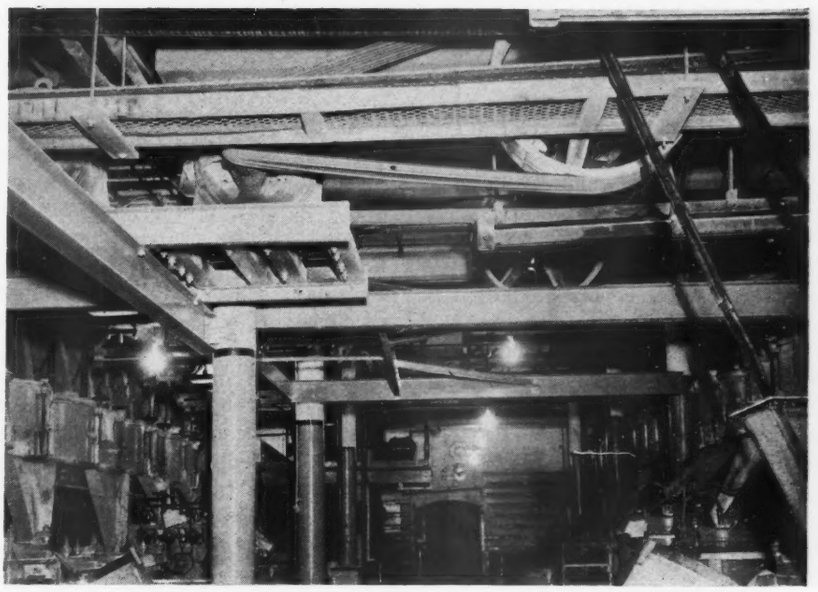
According to the estimate we would purchase 58 per cent more

power for 24 per cent additional cost by installing three-phase equipment and transforming current on our side of the meter for the 582-hp. load in two-phase motors.

Diesel engines were seriously considered; we were absolutely open-minded on the subject. The attending investment, however, was the largest obstacle to their adoption.

In this connection, space was also a problem. A more complete line of paint products that will promptly and properly meet demands naturally requires more warehouse space for finished stock, as well as for raw materials. The 1,500 sq.ft. of space made available by the removal of the corliss engine was very quickly utilized to meet storage requirements.

One of the most interesting problems had to do with the method of driving the machines. We readily decided upon group drives, but the problem of laying them out still remained. Arrangement of existing shafting prevented us to some extent from making changes that would have been preferred.

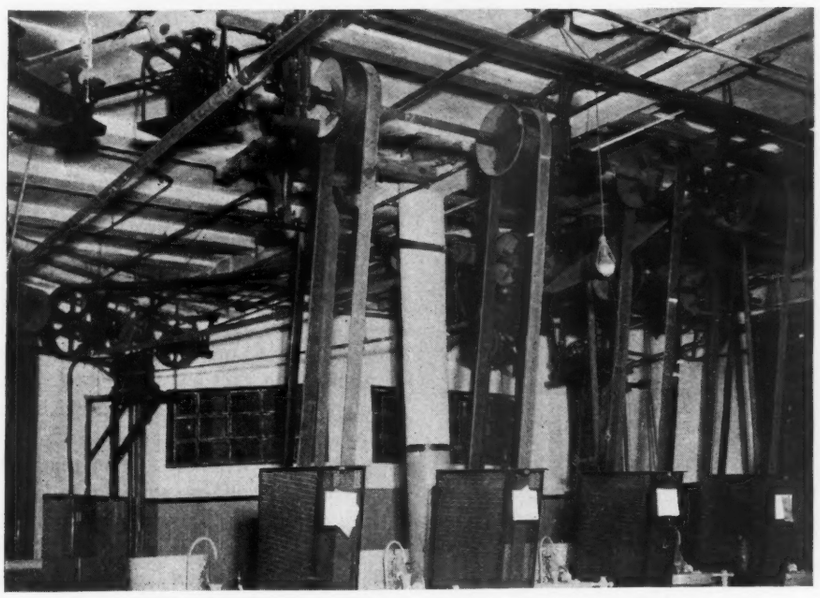


This is one of the old main lineshafts that was split into comparatively short lengths. Formerly driven from the floor below through a 36-in. belt, it now has its own motor driving through a V-belt

More, and Shorter Lineshafts

Selection of motor sizes for the lineshaft drives was important from the standpoint of original cost as well as future operating expense. Should we group mixers together, and mills together, or put mills and mixers and thinning tanks in a vertical hookup? Certain products require mixing alone, or a longer mixing time than grinding time. Contrast the production of an oil paint at the rate of 85 gal. of paste per mill hour on a 36-in. single-stone mill with that of a fine baking enamel where the yield is ¾ gal. of paste per mill hour on sets of 20-in. stones in tandem. There is quite a difference in power consumption here.

After considering load factors by types of mills, as well as mill and mixer activity expressed on production schedules, we were ready to break the existing lineshaft into suitable lengths. Because of the varied colors produced in a paint plant, it is not always practicable to clean down a mill after each batch; rather, it is desirable to operate the mills continuously by basic color groups. This consideration simplified the load question to some extent, because of the fact that black pastes weigh an average of 8 lb. per gallon, red lead pastes 40 lb., and whites about 20 lb. Thus, we were able to arrive at reasonable load conditions by averaging the production of each group.



With smaller groups it was possible to place the shorter lineshafts at whatever angle best meets requirements

Extra Power for Peak Loads

Our next problem was of greater consequence, due to the fact that in so far as production is concerned the paint business has two peaks and two valleys each year: spring and fall are very busy, summer and winter are subnormal. Here is how we circumvented this problem: an extra motor was included in the installation to provide for the peak loads, and was tied into the main drive by a jackshaft that permits it to be disengaged in the slack seasons.

After a series of plans had been drawn it was decided that seven 50-hp. motors would best do the job. With these motors the load could be

evenly distributed, with the added advantage of common replacement parts and interchangeability of units.

Six of these motors were mounted on platforms consisting of 10-in. I-beams bolted to columns and supported from bearing plates in the wall. To these I-beams 8-in. channel irons were secured and the motor platforms were constructed of 4-in. yellow pine bolted to the channels. This mounting requires no usable space, which is a decided advantage.

The seventh motor, set up on a tank storage platform, is also conveniently out of the way.

Between Motor and Lineshaft

Due to the different speeds required on the several lineshafts it was considered advisable to use V-belt drives on four of the installations, and they have served well. In one instance a countershaft was necessary because of lack of space for motor pulley. On another drive an inclosed silent chain was used.

Incidental motor drives were necessary in addition to these units employed in the direct manufacturing departments. The old engine did a reliable but expensive job in supplying steam to drive one of the four elevators, three pumps for liquid raw materials, and the ventilating fan. These services were motorized. No serious problems were presented in these installations; there was only the matter of selecting the proper motor for the requirements.

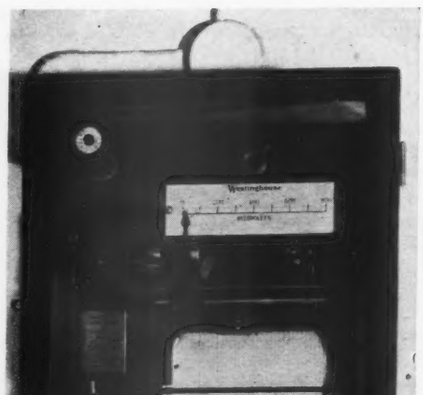
Costs Cut by Limiting Demand

The new power contract imposes heavy penalties on high kilowatt demands and it was, therefore, incumbent upon us to limit these demands to reasonable peaks in order to enjoy the lower kilowatt-hour cost which was indeed the major reason for this entire changeover. A demand limiter installed in the superintendent's office, with the control adjusted on the basis of expected monthly production, was the solution to this problem. A buzzer warns the plant office of excessive demands, and a system of signal bells throughout the manufacturing department notifies the foremen that the load must be decreased.

There are, however, many instances when we elect to pay the penalty of higher demand charges rather than incur overtime or withhold production, with the resulting back orders and added costs of operation.

In this connection, a review of our heavy manufacturing operations on the basis of kilowatt demands taken at 15-min. intervals for two months showed a consistent peak load at about 10 a.m., and 2 p.m. each day. Since each kilowatt costs us $2.30 or $2.18 (depending upon the bracket we are in) it was to our advantage to smooth production out evenly over the eight-hour day. Machinery that could be run in the low-demand periods, or after hours, was scheduled by the production department for operation at these times, in order to keep energy costs down.

Finally, it was desired to estimate how many tons of coal would be needed for heating our buildings, and for hot water. Heating cost was calculated by taking the average outside temperatures for each month in the heating seasons during the past 50 years, and assuming a room temperature of 68 deg. F. Allowances were made, of course, for heat loss through walls, windows and doorways; infiltration losses were figured at two air changes per hour.



Watches the electrical load peaks, sounds an alarm in all manufacturing departments when they exceed the desired maximum. This demand limiter has been an important factor in keeping energy costs down

Aside from the quantity of hot water and live steam used to scour paint tanks, an arbitrary allowance of 3 gal. of hot water was made per person per working day for showers and washing up. On the basis of 45 per cent boiler efficiency, the tons of coal necessary were then calculated to give the estimated annual cost.

Since this changeover was made our management has looked closely for further economies in our heating and power. Recently an automatic stoker was installed, and the heating system converted to low pressure in order to make a further saving.

•

Case of Ingenuity

T. C. SUTHERLAND
Mechanical Engineer
National Acme Company, Cleveland

THE ENGINEERS and rigging crew of a large manufacturing plant had to get a 35-ton hydraulic machine into a hole in the ground.

The hole had been completed and lined with brick according to specifications. Upon arrival of the machine it was found that there was only a 6-in. clearance between the walls of the hole and the machine. There was no provision for hooks on top of the machine. If chains were used it would be necessary to place blocks on the floor of the hole in order to remove them.

Numerous ideas had been discussed and found impractical. It was a laborer employed to sweep the factory floor who finally showed a unique method that worked.

The sweeper could not explain his idea but agreed to do the job after a little persuasion and an offer of some prize money. He was given an advancement which he said was necessary.

The next morning the sweeper entered the factory grounds leading a convoy of trucks loaded with ice. Men unloaded the trucks and filled up the hole with ice. The machine, on wooden rollers, was pushed onto the ice which was flush with the ground. Steam lines hastened the melting of the ice. The machine settled down safely and satisfactorily.

A. C. Wave Windings

Tables and connecting diagrams for windings that have 3½ slots per pole per phase, with rules covering front, back, and short pitches

A. C. ROE

IN THE preceding article, October issue, tables and diagrams were given, covering the connection of wave windings that have three slots per pole per phase. In addition, the types and arrangement of phase coils were discussed. Windings having 3½ slots per pole per phase will now be taken up, with an explanation of the meaning of the terms front, back, and short pitch as applied to a.c. wave windings.

In these articles the proper pitch is given for each connecting diagram and with each connecting chart. The same pitches apply for any number of poles and slots that come within the slots-per-pole-per-phase grouping for which any one diagram or connecting chart is used.

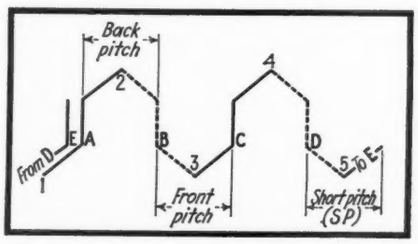


Figure 1. Pitches in a four-pole winding having two coils in series

SPP Governs Pitch

On first thought it may seem strange that, regardless of the number of slots and poles, when the number of slots per pole per phase is the same, the pitches are the same. Nevertheless, it is true. This is one of the points in which the a.c. wave winding differs from the d.c. wave winding; in the latter the connecting or lead pitch changes with the number of single coils.

Back Pitch—The term back pitch means practically the same thing as coil pitch, since it locates the slots that the coil spans at the rear of the core. It should be remembered that all coils for a.c. wave windings are of the one-turn, open-on-the-front-end type; two, three, or more turns are obtained by using four, six, and so on, conductors per slot and connecting them in series at the front end.

What Front Pitch Means

The back pitch of all coils in any one winding is the same; that is, all span the same number of slots. Thus, with one-piece coils the back pitch is mechanically set. Referring to Figure 1, the connection between slots *A* and *B* is the back pitch of the complete open-end coil *1-A-2-B-3*, of which *1-A-2* is the top half and *2-B-3* the bottom half.

Front Pitch—The a.c. wave winding does not use a commutator; therefore, the front ends of the coils must be connected together by clips, to form the basic series of coils. The number of coils in the series is equal to one-half the number of poles. This series of coils encircles the core once.

In Figure 1 the two coil series of a four-pole winding, as *1-A-2-B-3*, and *3-C-4-D-5*, are shown connected in series. The bottom half, *2-B-3*, connects across the front to the top half, *3-C-4*, and this connection between slots *B* and *C* is the front pitch.

Winding Pitch—A study of Figure 1 and the foregoing rules shows that the addition of the back pitch

Checking Chart IV*

3½ Slots per Pole per Phase

No. of Slots	No. of Poles	Polarity	Phases C					Phases B				Phases A		
		↑	8	7	6	5	...	4	3	2	1	Z	Y	X
42	4	↓	...	18	17	16	15	14	13	12	...	11	10	9
		↑	29	28	27	26	...	25	24	23	22	21	20	19
		↓	...	39	38	37	36	35	34	33	...	32	31	30
63	6	↑	50	49	48	47	...	46	45	44	43	42	41	40
		↓	...	60	59	58	57	56	55	54	...	53	52	51
84	8	↑	71	70	69	68	...	67	66	65	64	63	62	61
		↓	...	81	80	79	78	77	76	75	...	74	73	72
105	10	↑	92	91	90	89	...	88	87	86	85	84	83	82
		↓	...	102	101	100	99	98	97	96	...	95	94	93
126	12	↑	113	112	111	110	...	109	108	107	106	105	104	103
		↓	...	123	122	121	120	119	118	117	...	116	115	114
147	14	↑	134	133	132	131	...	130	129	128	127	126	125	124
		↓	...	144	143	142	141	140	139	138	...	137	136	135
168	16	↑	155	154	153	152	...	151	150	149	148	147	146	145
		↓	...	165	164	163	162	161	160	159	...	158	157	156
189	18	↑	176	175	174	173	...	172	171	170	169	168	167	166
		↓	...	186	185	184	183	182	181	180	...	179	178	177
210	20	↑	197	196	195	194	...	193	192	191	190	189	188	187
		↓	...	207	206	205	204	203	202	201	...	200	199	198
231	22	↑	218	217	216	215	...	214	213	212	211	210	209	208
		↓	...	228	227	226	225	224	223	222	...	221	220	219
252	24	↑	239	238	237	236	...	235	234	233	232	231	230	229
		↓	...	249	248	247	246	245	244	243	...	242	241	240

*To be used with Figure 4 and Connecting Table IV.

Connecting Table IV*

3½ Slots per Pole per Phase

No. of Poles	No. of Slots	A Phase Bottom A1	A Phase Leads A*	A Phase Top A3	A Phase Leads A4	B Phase Bottom B1	B Phase Leads B*	B Phase Top B3	B Phase Leads B4	C Phase Bottom C1	C Phase Leads C*	C Phase Top C3	C Phase Leads C4	Short Pitch Connections SP 1–3–5	Short Pitch Connections SP 2–4–6
4	42	↑ 1	32	30	20	↓ 15	4	2	34	↑ 29	18	16	6	3	2
6	63	↑ 1	53	51	41	↓ 57	46	44	34	↑ 29	18	16	6	3	2
8	84	↑ 1	84	82	72	↓ 57	46	44	34	↑ 29	18	16	6	3	2
10	105	↑ 1	94	92	82	↓ 36	25	23	13	↑ 71	60	58	48	3	2
12	126	↑ 1	116	114	104	↓ 36	25	23	13	↑ 92	81	79	69	3	2
14	147	↑ 1	137	135	125	↓ 57	46	44	34	↑ 113	102	100	90	3	2
16	168	↑ 1	158	156	146	↓ 57	46	44	34	↑ 113	102	100	90	3	2
18	189	↑ 1	179	177	167	↓ 57	46	44	34	↑ 134	123	121	111	3	2
20	210	↑ 1	200	198	188	↓ 71	60	58	48	↑ 141	130	128	118	3	2
22	231	↑ 1	221	219	209	↓ 78	67	65	55	↑ 155	144	142	132	3	2
24	252	↑ 1	242	240	230	↓ 78	67	65	55	↑ 176	165	163	153	3	2

*See Figure 4 for connecting layout

Front pitch = 1 and 11; back pitch = 1 and 12; short pitch (SP) = 1 and 10

and the front pitch, expressed in slots, is necessary in order that the third slot may be picked up to continue the series; or slots *A-B-C* are joined together by the front and back pitches.

The sum of the front and back pitches in slots is called the winding pitch; it is the distance in slots between any two like poles. It will be seen that the winding pitch of a.c. windings is similar to the lead pitch of d.c. windings.

Location of Short Pitch

The winding pitch is also the pitch, in leads, on the front end between the top and bottom leads of any one single coil; for example, between leads *1* and *3* of coil *1-A-2-B-3*, as Figure 1 shows.

Short Pitch—As mentioned above, there is a series of coils, as 2, 3, 4, and so on for 4-, 6-, or 8-pole windings, that encircle the core, but at the end of this series, as lead *5* in Figure 1, the front pitch must be shortened one slot to prevent the series closing on itself.

In Figure 1 the series of two coils ends in slot *D* and at point *5;* a full front pitch would connect slots *D* and *A* and form a closed circuit. Therefore, to continue the series one slot must be dropped from the front pitch and slots *D* and *E* connected together by the short pitch (*SP*).

Therefore, a short pitch always occurs at the end of the series of coils, and since there are six separate sections in any three-phase wave winding, there will be six places where the short pitch occurs.

The top and bottom leads of all coils at a short-pitch section must be shortened one-half a slot; with coils having conductors of light section the leads can be shaped while winding, but with heavy conductors special coils must be used. Some of these coils will have short top leads; others will have short bottom leads.

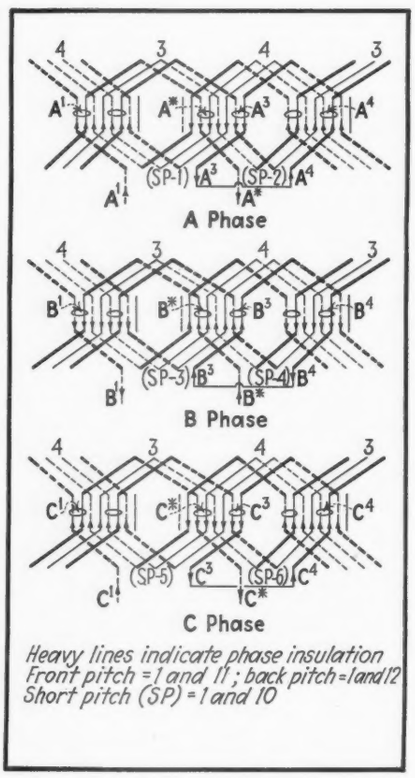

A Phase
B Phase
C Phase
Heavy lines indicate phase insulation
Front pitch = 1 and 11; back pitch = 1 and 12
Short pitch (SP) = 1 and 10

Figure 4. Connecting diagrams for a.c. wave windings having 3½ slots per pole per phase. These diagrams to be used with Connecting Table IV

The back, front, and short pitches are all derived from the winding pitch which, expressed in slots, is equal to the number of slots divided by one-half the number of poles. Winding pitch expressed in slots is also equal to six times the number of slots per pole per phase.

When the winding pitch is an even number, divisible by two, the back and front pitches expressed in slots are the same, and are equal to one-half the winding pitch.

When the winding pitch in slots is an odd number, not divisible by two, the back pitch is one slot more than the front pitch. Or, dividing the winding pitch by two, add the fraction to the back pitch, making it a whole number. The sum of the back and front pitches should equal the winding pitch.

Always One Slot Less

The short pitch is always one slot less than the front pitch, regardless of whether the winding pitch is odd or even, and occurs at six points in the winding: back of the *A3* and *A4*, *B3* and *B4*, *C3* and *C4* leads, or between *A1* and *A3*, *A** and *A4*, *B1* and *B3*, *B** and *B4*, *C1* and *C3*, *C** and *C4* leads, as Figure 4 shows.

A succeeding article scheduled for early publication will cover the connection of windings having four slots per pole per phase.

DATA SHEET

19 Stunts to Keep Safety Alive

Stunt No. 1—Safety Boosters' Club

This club, composed of keymen, superintendents, and foremen, lifted the Safety Committee plan to a higher plane. At weekly meetings, sub-committee chairmen were required to present complete reports of their findings. The slogan of the club was "90 days or Bust."

Stunt No. 2—Loyal Offer of Safety Boosters

Built on an endless chain basis starting with the initiation of one outstanding employee who signed a pledge for which he received an L.O.S.B. lapel button. He was permitted to recommend three men known to be safe workers. In a brief period 1,500 pledge cards were filed.

Stunt No. 3—Safety Boosters' Club Bulletin Board

Used to publish club news and safety posters. We included a scoreboard which compared the accident standings of eight large projects. Batting averages were based on frequency rates; team standings, on severity rates.

Stunt No. 4 Safety Boosters' Club Sergeant-of-Arms

A member of the original club was furnished with a cap, star, and oversized club. When unsafe practices were noted by members, the offender was hauled before a board of inquiry by this pompous individual, and usually paraded through the plant in a roundabout way to court.

Stunt No. 5—Accidometer

An accident meter was devised to record the number of consecutive days each department had gone without a lost-time accident. The slogan on the meter was, "Won't you feel like hell if you spoil your foreman's record?"

Stunt No. 6—Hand-Painted Bulletins

Illustrated in a bizarre manner the use of tools that had caused accidents and devices for accident prevention.

Stunt No. 7—Green Hammer Man

Handles of several ordinary hammers were painted bright green. The hammers were turned over to a squad of men and water boys whose job was to comb the construction project for upturned nails and bend them down.

Stunt No. 8—Target Score Board

This board came after the "accidometer" and was divided by departments. An accident meant that a colored metallic disk was attached to an outer circle.

Stunt No. 9—No-Accident Calendar

A "No-Accident Month" calendar was designed for the campaign period, and daily sheets on the calendar pad carried different slogans.

Stunt No. 10—No-Accident Campaign Board

To stimulate lagging departments to greater effort in the prevention of time-losing accidents, special indicating devices were designed and displayed at strategic spots:

a. A campaign board symbolized strong effort to "ring the bell." Each day accomplished without an accident moved a colored map pin farther up the indicator board.

b. Another board was symbolic of electric railways operation. Small cars were moved one tie forward for each day without an accident.

c. A campaign indicator recorded the number of consecutive no-accident days in each department.

Stunt No. 11—Trainmen's Accident-Prevention Contest

Another campaign board provided a method by which electric-railways trainmen could visualize team progress, similar to the board mentioned above. Each type of accident was identified by card appendages, and the small toy cars progressed along the track to the car-barn goal. Suitable prizes were awarded the winning team.

Stunt No. 12—January Minimum-Accident Calendar

No-accident campaigns are for the most part pleasant to look back upon. But some created so much interest that an unnatural tension was observed in the employees. One campaign failed in the final stages when a worker who had apparently been keyed up to a nervous state was involved in a serious accident. Therefore, the next drive against accidents brought a campaign calendar, advertising the new policy, which was to reduce accidents to a minimum. This drive was much more satisfactory.

Stunt No. 13—Safety Picture Reel

Provided a means for reproducing a collection of photographs in the company magazine in an unusual and interesting way.

Stunt No. 14—Accident Jinx Cat

The "Accident Jinx Cat" mounted on a base was devised as an award to the group responsible for breaking a departmental no-accident record. The group to which this jinx was awarded was required to hold it until another group took it from them by having an accident, or until the whole department had worked a year with an unblemished record.

Stunt No. 15—Display Boards

Developed to portray the many methods used to maintain employee interest in safety. On them were various types of educational literature, including letters, posters, blotters, and such awards as watch fobs and keychains.

Stunt No. 16—Safety Dollar

Plan comprised the distribution of sets of thirteen sheets of papers numbered in series and looking like dollar bills. Every employee received a safety dollar with each pay for thirteen consecutive pay days and was urged to save a complete set for the purpose of winning cash prizes offered to those holding lucky numbers.

Stunt No. 17—Safety Pennants

Awarded to power plants, shops, mines, and other departments having large numbers of employees for accomplishing records of 30 days without a lost-time accident. A gold star was added for each additional 30-day period.

Stunt No. 18—Safety Trolley Car

To stimulate interest in safety on the part of the general public and particularly the car-riding public, slogans were permanently painted on certain trolley cars. These cars attracted much favorable comment and assisted in the reduction of public accidents.

Stunt No. 19—"Safety At All Times"

This slogan was painted in large letters on the face of a building which was perched on the top of a fair-sized mountain overlooking a coal mining property. It not only has a visible effect on the 500 mineworkers, but advertised to the world that safety was practiced there.

H. F. WEBB, *General Safety Director, West Penn Power Company, Pittsburgh*

Presented at the Annual Safety Conference of National Safety Council

DATA SHEET

How Can We Make New Men Safety-Minded?

THE APPROACH to the problem is through these questions:

What kind of organization? Are the executives safety-minded? Are they sympathetic toward a safety program—or do they know what a safety program is?

What kind of supervision? Do we have lip service, bulletins, and hullabaloo, but no follow-up?

What kind of instruction? Do we give the new man a book of rules, a number, put him at a machine, and expect him to find his way around?

Do we have safety committees? Are accidents followed up and responsibility fixed, or do we hope that we won't have another accident and that Tom Smith will be more careful in the future?

A new man in a plant that is not organized to combat accidents is in a fair way of being subjected to hazards of his own efforts to work safely. A greenhorn in a safety-conscious plant who is beginning a job after proper instructions, and doing that job under continuous supervision, is a relatively safe man.

The employee can sense the attitude of management. He knows whether management is sincere in its safety program. The first thing to do to "make a new man safety-minded" is to make the "tops" safety-minded. How many of your big executives know what the safety program is in your plant? Does the president or any other major officer ever talk with you in a manner that would indicate that he knows a few of the details?

Do you ever get a chance to impress the executives with the idea that your accident prevention work is just as important as production and sales?

Do your executives ever sit in on the safety meetings? Are they interested?

Here is the way we approach the new employee problem:

1. A new employee receives explanation of our safety program. We tell him what it means to him, to his family, and to all the company to be a safe worker.

2. He is then taken to the foreman and introduced. We make him feel at home in his position, and he is told what is expected of him in work, deportment, and general attitude.

3. Foreman talks to him, then assigns him to job as an assistant to old and experienced employee. He spends one or two weeks on that job until he gets accustomed to routine and noises. This is the probation period, during which time he learns about the machine he is to operate.

4. He is put on the simplest machine, but gets full instructions on:

   a. How to operate it and what to do;
   b. If something goes wrong, he calls assistant foreman. He is not permitted to try to fix or make repairs.

5. Periodic check-up several times a day.

   a. Material—how piled, etc.;
   b. How he is handling machine;
   c. No "monkeying" with guards; if guard is removed, a worker is sent home for two days; second offense, three days; third offense, dismissal.

6. General safety meetings of entire plant are held twice a month. Report made of all accidents—no names mentioned. Ten department heads are held responsible. We do mention the department the accident occurred in; no comments are made at open meeting; details are handled by the safety committee.

7. Suggestion Box. All questions and suggestions considered, and acknowledgment is made:

   a. Either in open meeting, or

   b. Taken up individually with the man making the suggestion. This keeps interest stirred up. It develops consciousness that company is interested.

In our work with the new men we don't forget the old men. The old employee needs checking and supervision too.

An important thing to keep in mind is this. An old employee on a new job or a different kind of machine is a green man so far as his new job is concerned. He needs instruction and supervision as well as the new man does.

No better example of this can be found than in the experience of many industries during the depression. During the year of the rehiring period after the depression shutdown, accident frequency of some 100 industries in the St. Louis Safety Council's Inter-Plant Safety Contest increased from 6.8 to 12.58, an increase of 85 per cent.

What caused these accidents? Who was having them? Not new, green men, but old employees who were being put back to work. No instructions—no check-up to see if the men knew what to do. Just because they were old employees it was taken for granted that they knew everything about all jobs.

The company takes nothing for granted. When we employ a man for a job we see, first, that he is fitted for the job; second, that he understands his job; third, that he also understands his responsibilities.

No man is taken on "green" and expected to handle a process job. He has to be broken in, first, as a helper on material, trucking, stacking, etc. Then he assists an operator, begins to get accustomed to surroundings, noises, machine operations, etc.

After that he is given a machine if he wants it but only after he has been instructed. After he begins as an operator he is checked, and the machine is checked regularly. Nothing is taken for granted, and everyone from top to bottom is sold on safety.

Our firm joined the St. Louis Council in 1929. Our frequency rate was 30.0 in 1928 and you could measure the years of service by the absence of our workmen's fingers. Our first year in the Inter-Plant Safety Contest saw our frequency drop to 3.88. In 1930 we reduced our frequency to 1.41, and in the last four and a half years had no lost-time accidents.

Figures used sparingly are more eloquent than words. Here is a brief outline of our progress since 1928:

Year	*Man-Hours*	*Accidents*	*Lost-Time Injuries*	*Days Lost*	*Medical Costs*
1928.....	No Record	103	30	207	No Record
1929.....	1,030,073	81	3	31	$916.50
1930.....	708,900	24	1	41	346.00
1931.....	572,084	21	0	0	260.19
1932.....	407,659	2	0	0	41.50
1933.....	631,746	12	0	0	179.00
1934.....	597,913	11	0	0	155.50
1935 (1st 6 months).	287,580	9	0	0	74.00

EMIL C. SCHULTES, *Safety Director, C. Hager & Sons Manufacturing Company, St. Louis*

Presented at the Annual Safety Conference of National Safety Council

OPERATING SHORTS

Motor Base for Cone Pulley Drive

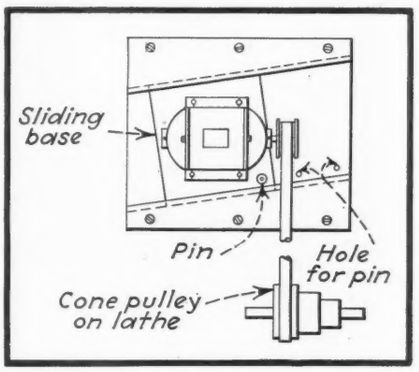
G. H. HILL, *Works Engineer*
Lamb Knitting Machine Corporation
Chicopee Falls, Mass.

When a number of belt-driven bench lathes with cone pulleys were changed to individual drive it became necessary to devise some quick and simple way of changing the position of the motor in order to obtain the different speeds required. Hence, the motor mounting shown in the sketch was designed.

Lathe speeds are changed by taking out the pin and sliding the motor forward or back until the holes in the base line up; then the pin is replaced to hold the motor in position.

The holes are located in the base where the motor pulley lines up with each step in the cone pulley. As will be seen, the motor slides at the proper angle to keep the belt tight on each of the steps.

This motor mounting is not limited to bench lathes; it can be used with any type of cone-driven machine that is changed from belt to motor drive.

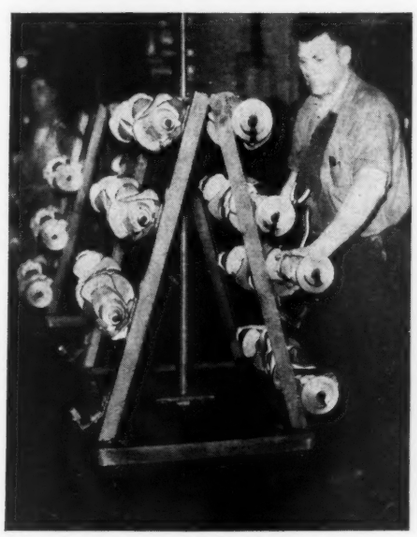


Mr. Hill's contribution has been awarded the $10 payment offered by the editors for the best Operating Short submitted during the past month.

Fixtures to Fit the Load

SOURCE, *Packard Motor Car Company*
Detroit

Where a conveying problem involves diversified shapes and sizes of material to be handled, the efficiency of the solution may depend in large measure upon the fixtures, carriers, and other (below-the-hook or above-the-carrying-surface) devices by which the loads are tied into the conveying equipment. Many excellent examples are in use throughout the newly equipped "One Twenty" plant.



For instance, consider the monorail installation on the motor assembly line where the finished crankshaft is handled. This monorail uses a hand-push carrier, wedge-shaped so that the crankshafts may be loaded on both sides of the carrier and lie there of their own weight, without the necessity for any locking devices. Consequently the carrier comfortably handles its full load of 30 shafts.

At the points where the shaft rests upon the carrier frame, the frame carries fiber pads. Thus the highly polished and precisely machined crankshaft journals are protected against scratches and careless bumping. As it is, with the pads always there, workmen are able to put the shafts into the carrier and take them out without bothering to be gentle—which speeds up production and cuts damage in process.

Coding Repair Jobs for Future Identification

JACK BEATER, *Manager*
Harley Electric Co., Fort Myers, Fla.

If often happened that jobs would come back to the repair shop with the claim that the machine had been recently repaired and had failed to give satisfactory length of service. Looking up the job card in such cases took up a lot of valuable time, and invariably we found that the job had been done one, two, or even three years earlier, instead of the few months claimed.

To eliminate the trouble of searching into old records we adopted several years ago a system of coding all jobs. In specified places on various sorts of equipment we stamp certain figures which tell us at a glance what job was performed on the machine in question, and in what month and year it was done. For example, the figures HEB104 stamped on a motor have the following meaning to us: HE stands for our concern—Harley Electric Co., the B tells us that the job consisted of fitting a new set of bearings, and the 104 means that the job was done in the tenth month—October—of 1934. In the same way a W would mean that the motor was rewound, a C would indicate commutator repairs.

Since adoption of this system we have saved much time and argument with customers. Our quick identification of the job, together with the date of the work, defeats chiselers and wins the respect of those customers who have been honestly mistaken.

One valve manufacturer hard-faced drills used for countersinking operations on castings. Cobalt-chromium-tungsten alloy increased life before resharpening four to ten times.

Likes Grounded-Neutral, 2-Phase, 3-Wire System

T. W. LAWSON
Foreman of Maintenance
Radio Condenser Company
Camden, N. J.

After operating a grounded-neutral, two-phase, three-wire, 240-volt system in our factory for two years under most all conditions of motor operations, from the vibra-

tions and knocks of punch-press operations to the destructive atmosphere of a plating room, I can heartily recommend a grounded-neutral system because of these advantages:

1. The electrician can locate the neutral wire immediately, since the test-lamp or meter reading to ground is zero.

2. The usual practice of doubling-up on fuses for the neutral is eliminated. A piece of $\frac{3}{8}$-in. or $\frac{1}{2}$-in. brass pipe, two or three inches long, takes the place of the neutral fuses from 30 to 60 amperes. Strap copper can be used for circuits above 75 amperes. Then these "doubled-up" fuses are prevented from getting into the outside legs of the circuits by mistake.

3. The danger of impressing overvoltage on the repairman's test lamps or meter is eliminated. Making all tests to ground renders it impossible to get more than normal single-phase voltage.

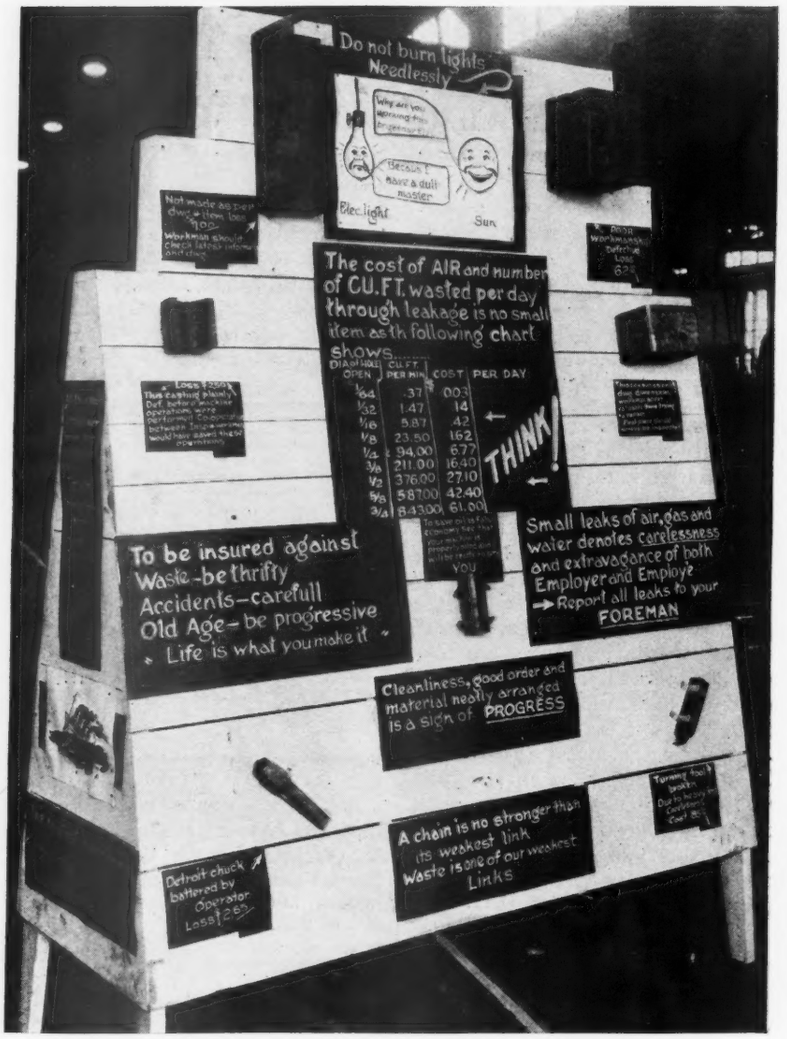
4. Localizing of accidental grounds is facilitated. With the ungrounded system, an accidental ground in one portion of the factory may shut down equipment in a department far removed from the affected area, due to the fact that an unindicated, accidental ground has accumulated in that department.

5. With one wire permanently grounded we need not worry about its becoming accidentally grounded; therefore the accidental grounding hazard is reduced 33⅓ per cent.

6. On a permanently grounded two-phase, three-wire, 240-volt system, 240 volts is the highest voltage that can be received through a shock to ground. However, on an ungrounded system it is possible to receive 240x1.1414 or 339 volts to ground. This occurs when an outside leg becomes accidentally grounded, and the opposite outside leg is touched.

Finally, the saving in fuses and switching devices is an important consideration that must be apparent to the operating engineer.

Pumps in an isolated pump house are kept from freezing by electric oven heaters with automatic temperature control. Heating with fuel would have required an attendant.


Do not burn lights Needlessly
Why are you spoiling this picture?
Because I have a dull master
Electlight
Sun
The cost of AIR and number of CU.FT. wasted per day through leakage is no small item as the following chart shows
DIAM HOLE OPEN
CU.FT. PER MIN
COST PER DAY
1/64 .37 .03
1/32 1.47 .14
1/16 5.87 .42
1/8 23.50 1.62
1/4 94.00 6.77
3/8 211.00 16.40
1/2 376.00 27.10
5/8 587.00 42.40
3/4 843.00 61.00
THINK!
To be insured against Waste-be thrifty Accidents-carefull Old Age-be progressive Life is what you make it
Small leaks of air, gas and water denotes carelessness and extravagance of both Employer and Employe
Report all leaks to your FOREMAN
Cleanliness, good order and material neatly arranged is a sign of PROGRESS
A chain is no stronger than its weakest link
Waste is one of our weakest Links
Detroit chuck battered by Operator
Lesson

Display boards showing waste materials and their cost have served Westinghouse Electric & Manufacturing Company, East Pittsburgh, in making employees waste conscious. By exhibiting damaged tools and defective parts and their values the cost of carelessness and waste is impressed upon the minds of all in the plant

A Bath and Bake for Dirty Motors

H. D. JEFFERSON, *Chief Electrician*
Hawaiian Pineapple Company
Honolulu, Hawaii

Users of motors that are subjected to unusually severe conditions may be interested in the method we use for cleaning our machines. We operate more than 1,000 motors in the cannery and byproducts plant. Many of these motors are subjected to water, steam, and citric acid and sugar solutions, the latter two being present in the atmosphere in the form of vapor.

Motors whose windings have become coated with mixtures of sugar and citric acid are treated as follows:

The stator is submerged in a tank of water having a steam inlet. Sodium bicarbonate is added in sufficient quantity to neutralize the acid. The steam valve is opened, the water allowed to come to a boil, and the stator is rapidly moved up and down through the boiling water by means of an air hoist, until all traces of sugar have been washed out. This process is repeated in tanks of fresh hot water until the final drippings no longer show the presence of acid or alkali, as determined by the use of blue and red litmus paper. The stator is then baked at 250 deg. F. for a period of time that depends on its size. For example, a 50-hp. stator is baked for 12 to 14 hours.

Then the stator is transferred to a processing tank, where vacuum of 28 in. or more is applied for about 15 min. to remove the last traces of

moisture. A quantity of Glyptal varnish No. 1154, sufficient to cover the windings, is admitted from a storage tank through an inlet at the bottom of the processing tank. The vacuum is broken and air pressure at 75 lb. per sq.in. is applied from the top of the tank. It greatly reduces the size of the air bubbles trapped in the varnish. The air pressure is maintained for a short time in order to allow the varnish to penetrate into all parts of the stator. The valve at the bottom of the tank, through which the varnish was originally admitted, is then opened and the air pressure used to force the varnish back into the storage tank, thereby eliminating all handling.

Again the stator is baked for the proper time. After cooling, its resistance to ground, which is always the weakest point of motor insulation, should be infinity on a 100-megohm scale.

For cleaning motors other than those requiring water for a solvent, we have found that a mixture of two parts of gasoline and one part of carbon tetrachloride gives very satisfactory results. Such a mixture costs about 60 cents per gallon when made in batches of 150 gallons.

Insulated boxes built around fire extinguishers located out of doors will keep them from freezing with only a barn lantern or electric bulb to furnish heat.

Shop Coats for Foremen

WILLIAM PEASLEE
Works Manager, Cincinnati Milling Machine and Cincinnati Grinders, Inc. Cincinnati

Special shop coats with wearer's name embroidered on the breast are our latest method of dressing up our foremen and supervisors. The protection which his clothing receives encourages the wearer to present a better appearance in the shop, and there is no denying that good appearance helps to lend dignity to the foreman's position.

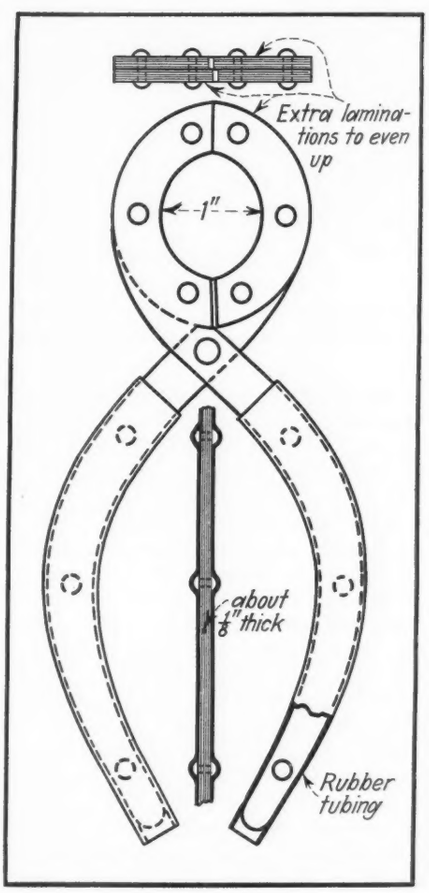
It is much easier to locate a foreman or supervisor now, and new employees have no difficulty in learning who is in charge. In addition, visitors to the plant carry away a better impression.

Looks Like Pliers, Indicates Current Flow

J. H. SAUVE, *Temiscaming, Que. Canada*

A handy, rugged device for determining whether current is flowing in a conductor is shown in the illustration. It is made from iron laminations cut to the shape of pliers. The joint is rather loose-fitting, since much of the usefulness and sensitivity of the device depend on absence of friction at this point.

When using this tester the upper end is closed around the conductor, over the insulation. If current is flowing, the jaws of the tester will tend to close. I have found that it is best to hold the tester loosely, with the little finger between the handles. If slight pressure is exerted with the finger the jaws of the tester will



open, but when the pressure is released the jaws will close, if current is flowing in the wire.

This tester has been found to be particularly useful in checking for single-phase operation of polyphase motors, and in detecting opens in rotor circuits to controllers and grids.

When used on rotor circuits the low frequency produces a pulsation of the tester that is easily recognized.

It is advisable, of course, to slip a piece of rubber tubing over each handle, to protect against possible shock.

Muslin in place of wire in the window screens of one plant insulates the drafting room against soot and dust, permits air and light to enter, can be changed readily.

Don't Let Drip Pans Become Popular

MARK BELL, *Passaic, N. J.*

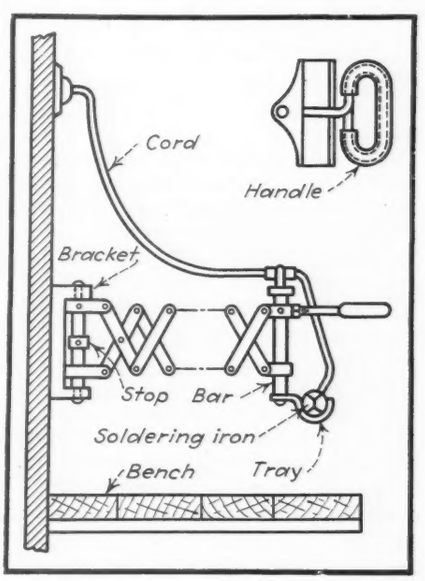
Never use a drip pan if you can possibly do without it. Always stop the drip at its source. If a gland is leaking steam or oil, stop the leak. Steam costs money, and oil needs separating and clarifying before it can be reused.

Soldering Iron Bracket— No Burns, No Hunting

JOHN A. HONEGGER, *New York*

In one plant which I visited recently considerable bench assembly is performed on flat electrical panels. At the conclusion of each assembly, certain leads must be soldered to connections. This means that, although a soldering iron must be kept at hand, it is not used continuously.

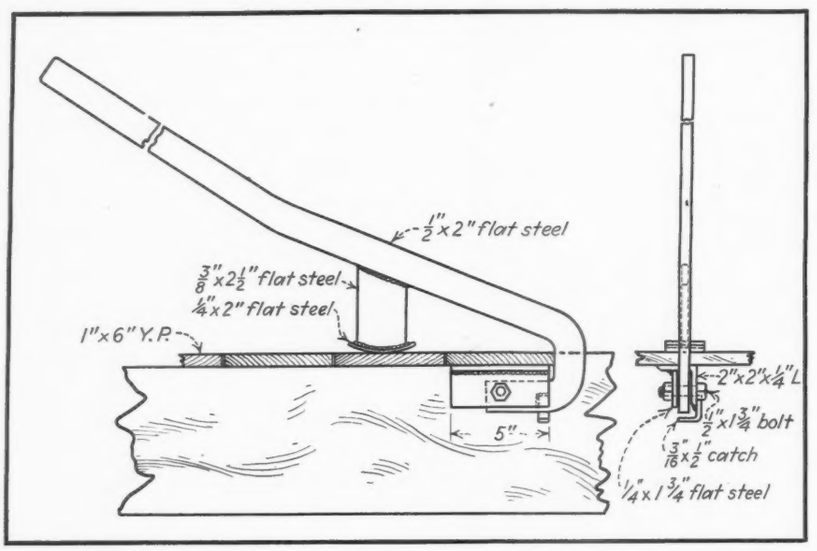
To allow two assemblers to use the



same iron, and to place the iron outside the working area so that operators will not be burned, a lazy tongs extension bracket is employed. It consists of a bracket to which the criss-cross straps are attached in such a manner that they can slide on the bracket. To keep the lazy tongs from extending too far beyond the critical supporting length, a stop limits the slide along the bracket.

The outer end of the tongs has an upright bar to which one end of the tongs is attached while the other is allowed to slide. At the bottom of this bar there is a tray in which the iron is supported or cradled. As the iron may conduct heat to the extension, an insulated handle is provided, by which the extension is moved to any desired position. An asbestos-covered cord is allowed to pass through an eye in the bar, and after allowing a generous length of cord to the iron, knots are made on each side of the eye.

This construction not only lends itself to irons, but to electric drills, small riveting and calking hammers, emery wheels, and buffing wheels.



A Tool for Pulling Flooring

E. H. TRICK, *San Antonio, Texas*

It recently became necessary to tear down a wooden building that had been erected as a machine shop 52 years ago. Some of the lumber in this building was second-hand material at the time of construction, so that when it was torn down the material was over 70 years old.

The floor of the second story was made of one by sixes, and the nails used were the old fashioned cut-iron variety, with square heads. We found also some round-bodied nails, with herringbone serrations along their entire length. These were even harder to draw than the square-cut iron ones.

The wood was so old that all life had gone out of it; it was extremely brittle, and the boards could not be removed with ordinary wrecking bars and claw hammers, without breaking them to pieces. As there was still a lot of service in them if they could be salvaged (a number of employees wanted them for walks, fences, garages, etc.), we made a special tool that would lift the board straight up off each joist, pulling the two or three iron nails up with it.

The tool consisted of a ½x2-in. steel bar about 6 ft. long, bent edgewise at one end to form a short hook, and having another slight edgewise bend about a foot above the hook, so that a workman standing erect could pull the hooked end under the edge of the flooring alongside any joist.

The hooked end was provided with a clevis made of a 2x2x¼-in. angle, 5 in. long, having a flat bar ¼x1¾x5 in. welded to it about 9/16 in. from the inside face of the dependent leg, so that the ½-in. bar would pass freely between them. A ½-in. bolt held them together, the clevis fitting loosely on the hook and having the travel of its inner end limited by a little catch welded to it.

Seven and a half inches back from the inside of the hook a rollable fulcrum was welded to the bottom edge of the 6-ft. bar. This consisted of a short piece of flat steel descending from the bottom edge of the bar with a curved piece of flat steel welded flatwise to its bottom end.

The operator merely had to pass the loosely hanging clevis under the floor board by hooking his bar under the exposed edge next to any joist, and bear down on the rolling fulcrum. The board was lifted straight up without being split, bringing the nails with it. By applying the tool at each joist the board came up along its entire length without splitting. With this tool a middle-aged Indian was able to pull up as much flooring as the best carpenter on the job; a moment's demonstration making him equally expert in its use.

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Files Resharpened, New Files Treated

SOURCE, *Westinghouse Electric & Manufacturing Company East Pittsburgh*

For several years we have been resharpening worn files, thus getting out of them four to five times as much service as can be had from new files. The process employed is the use of steam at ninety pounds pressure to blow fine silicon sand against the back of the file teeth. After this operation, the files are dipped in a mixture of two parts kerosene and one part machine oil, and then wrapped in paper.

When the used files can no longer be resharpened by the sandblasting process, they are sent to outside companies which recut them for us. This affords a considerable saving in an industry the size of ours, a fact readily seen by comparing the average cost of new files at 35 cents with the resharpening cost of only two cents each. New files are treated similarly upon delivery to our plants, and we are able to get much better service out of them.

SPECIAL NOTICE

$10 will be paid for the best Operating Short submitted during the month of December. The Editors are the judges. Other Shorts accepted will be paid for at attractive rates

Questions *and* Answers

Conducted by G. A. VAN BRUNT

Answers Wanted

Motors Sometimes Fail to Start

A number of our motors, 5-10-hp., three-phase, 440 volts, 60 cycles, are controlled by Start and Stop buttons. In several instances there are two pushbutton stations for a motor, so that it can be started or stopped from two different locations that are at a considerable distance from the motor and from each other. From time to time we have trouble in starting a motor. When one of the Start buttons is pushed, either nothing happens or the motor starts up and immediately stops. If the other Start button is pushed the motor usually will start and run normally. It has been reported that on two occasions a motor failed to stop when the Stop button was pushed. Could this be possible? What causes this trouble in starting and, possibly, stopping our motors? The motors, switches, and buttons seem to be in good condition. *J.F.—Cleveland*

ASSUMING that the wiring proper is in good condition, the trouble will most likely be found in the stop contacts of the control buttons, or in the contacts of the magnetic switch.

The stop contacts are doubtless of the normally closed type. If for any reason they remain open the motor will not start. The reason why the motor sometimes fails to stop may be found in badly burned or worn contacts in the switch, which weld together, holding the motor on the line regardless of efforts to stop it from the control stations.

Either cause of the trouble can easily be remedied. The Stop buttons should be adjusted and made to work freely, and the contacts on the magnetic switch should be dressed or renewed.

CHARLES R. MOTT, *Portland, Ore.*

THE TROUBLE is most likely due to poor contacts in the push-button stations. If there is a poor contact in a Stop button, nothing will happen when a Start button is pressed. This applies also when a Stop button sticks in its barrel, which frequently happens. When the coil contact in the switch is bad the motor will start and run so long as the Start button is held in, but it will stop when the button is released.

If the Start buttons stick in their barrels the motor may not stop when the Stop button is pressed.

Burned and pitted contacts in the switch, causing a very small area of the metal to carry the current and thus fusing it, will often hold the contactor in even though the coil is de-energized by pressing the Stop button. Weakened contactor springs or binding of the moving assembly may also prevent the contactor from dropping out. Of course, errors in wiring or a short circuit between wires will also result in abnormal operation.

Even though the pushbuttons and wiring are believed to be in good condition, their contact surfaces should be properly cleaned, the buttons freed in their barrels, and all terminal screws tightened.

L. A. HUNT, *Toronto, Ont., Canada*

THERE is probably a bad contact or poor connection in the coil circuit of the switch, if it fails to stay closed when the button is released.

If this is not the trouble, test for grounds in both pushbutton circuits, first disconnecting the wires from the switch panel, in order to get at each circuit to the Start and Stop stations separately.

I have known of instances where grounds, poor insulation, and damp wiring inside of the conduit have caused this same trouble. Replacing the wiring is the only remedy in such cases. R. L. HAMMOND, *Hartsville, S. C.*

Removing Oil From Pipe System

Exhaust from a steam engine was formerly distributed to heating coils in process equipment through a system containing about 300 ft. of piping. No effort was made to remove oil from the steam; so the inside of the pipe has oil on it. Now we want to distribute steam through this piping to a service in which oil is highly objectionable. How can we remove the oil film from this pipe? The possibility of circulating a caustic soda solution through the pipe has occurred to us, but it would be difficult to do and we doubt wehther such a solution would be very effective against the heavy oil. Have any other readers successfully met this problem? *A.P.W.—Baltimore*

Why Does Ammeter Needle Oscillate?

I have noticed at different times that when an ammeter is connected in the circuit of an a.c. motor there is a slow, oscillating movement of the needle. The period of oscillation seemed to be about 5 seconds. Some of the motors observed sounded like one with a slightly sprung shaft, although oscillation of the ammeter needle has been observed with new motors having shafts that were apparently perfectly aligned. I wish that some reader would explain the reason for this action.

L.P.H.—Sheboygan, Wis.

Method of Roughening Iron Floor Plates

Sheet-iron floor plates used around certain machines and in places where heavy trucking is done are very slippery when they become oily or wet. I shall appreciate it if readers will tell me the best and cheapest way of keeping these plates rough enough to reduce the chances of someone slipping on them. *C.S.—Detroit*

One Motor, Two Lineshafts

In laying out a group drive a question has come up as to whether it is better to drive two parallel lineshafts by belting from one to the other, or by using an extended shaft motor, with a pulley at each end. It is estimated that 25 hp. will be required to drive the two shafts, which are 28 feet apart. We do not want to use two motors; therefore, we shall have to use one of the methods mentioned above. Which do you recommend? Why? *K.D A.—Louisville*

WHEN a motor with extended shaft is placed between two parallel lineshafts, tightening the belt on one pulley loosens the belt on the other, assuming that the motor is moved backward or

forward. Hence, there may be difficulty in maintaining the proper tension to drive both shafts.

I recommend that a short jackshaft be mounted midway between the two lineshafts and driven from the motor at the lineshaft speed, using a pivoted motor base to maintain tension. Drive the lineshafts, which then are on 14-ft. centers from the jackshaft, by pulleys of as large diameter as possible, in order to get a high belt speed (but not over 3,000 to 3,500 ft. per min.) and a long wrap on the pulleys.

The question of maintaining tension in the two lineshaft belts now comes up. Unless these belts are of the least possible width and thickness considerable loss in tension will be taken care of by increased surface contact, as well as arc, on the larger diameter pulleys used, as compared to the smaller motor pulleys. Minimum recommended pulley diameters for 25-hp., 1,200-r.p.m. motors on lineshaft drives are about 9 in.; with an extended-shaft motor, each pulley carrying one-half the load, the pulleys could be 7 to 8 in., minimum diameter.

On a 9-in motor pulley driving a 300-r.p.m. jackshaft, giving a reduction of 4 to 1, a short-center drive belt would be in contact with approximately 10 to 12 in. of the circumference of the motor pulley, depending on the center distance. Under these circumstances tension must be maintained.

If 36-in. pulleys are used on the jackshaft to lineshaft drive, the belt is in contact with each pulley for about one-half the circumference, or about 56 in. Obviously, any decrease in tension with only 11 in. of belt in circumferential contact with the motor pulley is much more serious than a considerably greater slackening with five times as much belt in contact with the larger pulley.

The jackshaft may be eliminated, of course, by connecting one lineshaft directly to the motor and driving across on the 28-ft. center to the other shaft, using large pulleys to obtain high belt speed. This arrangement, however, would require a longer and more substantial belt guard and in my opinion would need more attention and not be so satisfactory as the jackshaft and shorter lineshaft belts on 14-ft. centers.

FRANK E. GOODING, *Fairbury, Ill.*

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What are your most troublesome problems? Free-for-all discussion of them will help you and other readers

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Synchronous Condenser Fails to Attain Speed

We have been having trouble with the synchronous motor of an m.g. set that consists of the motor, a 200-kw. d.c. generator, and a 30-kw. exciter, all on the same base. The synchronous motor is rated 345 hp., 0.8 power factor, 440 volts, 1,200 r.p.m., three-phase, 60 cycles. The field is wound for 250 volts, 11.9 amp. Control equipment includes a double-throw oil circuit breaker with short-circuiting contacts that close the Y-connection in the autotransformer; motor field rheostat; discharge resistor; line and field ammeters; overload and undervoltage protection; exciter field rheostat. We disconnected the generator at the coupling and have been using the motor as a condenser for power factor correction. The condenser is started with all field resistance in until it reaches synchronous speed; then field is applied and the autotransformer disconnected by the double-throw breaker. After this the condenser is thrown on the line and the field adjusted.

Two years after this set was installed, in 1928, the condenser would not come up to synchronous speed. The autotransformer was put on the second tap and there was no further trouble until 1932, when the same trouble appeared. It was solved by starting the machine on the third tap. Later the insulation between the field coils broke down near the core. The machine was repaired and operated normally for a time, but now we are unable to get more than 50 per cent of synchronous speed on starting. Where is the trouble most likely to be? How can I locate it?

G H.H.—Everett, Wash.

CAUSES for failure of a synchronous motor to come up to speed are to be found in the squirrel-cage winding, the a.c. winding, in the service to the motor, or in the starting equipment.

Starting current in this type of motor is high; therefore, any change in the plant load resulting in excessive voltage drop may cause the motor to fail to pick up speed. I would check the voltage across the feeders at the starter when this motor is thrown on the line. If the voltage remains within 90 per cent of normal check the voltage at the a.c. terminals of the machine.

The auto-transformers are usually connected to give 50, 60, or 80 per cent of full line voltage. Read the voltage while the motor is starting. If it is of the proper value, go over the motor carefully, particularly the connections in the squirrel-cage winding.

I believe that breakdown of the insulation in the d.c. coils was due to a poor contact in the short-circuiting switch, which would allow a dangerously high voltage to build up in the field winding. W. O. ZINN, *Chicago*

THE MOST likely reason for this motor failing to attain full speed is loose bars in the squirrel-cage winding which make poor contact with the endrings. The simplest way to determine whether this condition exists is by a careful examination.

Trouble experienced with the insulation of the field coils breaking down is likely due to starting with the discharge resistor out of the field circuit. During the starting period this resistor should be connected so that the motor field circuit is shorted through it. The high voltage induced in the field coils during the starting period will thus be dissipated. E. MOLINET

Engineering Department
Central Delicias
Delicias, Oriente Province, Cuba

THERE are several possible causes for this trouble, which makes it difficult to say exactly where the trouble may be located. I advise making a thorough check of all contacts and connections to the stator and field circuits, including the auto-transformers. The discharge resistance connections and field resistance contacts should be given particular attention. Connections where the bars of the amortisseur winding are attached to the endrings should also be closely inspected for loose or broken joints.

Such faults in the rotor circuit affect the starting characteristics of a synchronous motor in the same manner as an increase in the secondary resistance of an induction motor. The turning effort of the rotor is increased during the starting period, but the maximum speed to which the rotor will accelerate is lower.

If the field coils are connected in parallel, check them for an open circuit. One circuit may be open.

Again, any condition in the supply circuit that causes a reduced voltage to be impressed across the stator terminals reduces the starting torque and consequently the speed which the rotor attains. A poor contact in one leg of the supply circuit may so unbalance the phase voltages as to reduce the starting torque to a very low value.

J. L. YOUNG, *St. Marys, Ohio*

EQUIPMENT NEWS

Unit Heaters

Four models. Direct pipe suspension permits rotation through 360 deg. Individual expansion of tubes made possible by "expansion-bend" feature. Modine Mfg. Co., Racine, Wis.

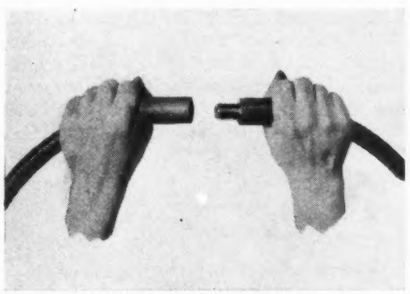
Scale

Small bench scale for general utility purposes. Platform dimensions, 16½x 18½ in.; capacity, 50-125 lb. Small size dial mechanism. Full floating type platform construction is such that none of the lateral motion is transmitted to lever system. All levers operate about fixed fulcrums. The Kron Co., Bridgeport, Conn.

Time Control

Automatic reset. Starts series of operations on a prearranged schedule. Returns to starting position in event of fuse blowout or power failure. Any interruption in operations causes timer to reset. Timing accomplished by adjustable cam construction. Starting and resetting require no re-meshing of gears. Automatic Temperature Control Co., 36 East Logan St., Philadelphia.

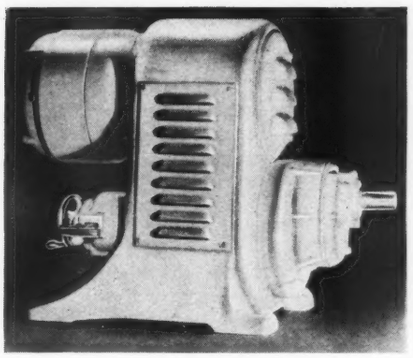
Connector



For welding or electrode cable. Quickly detachable. Plug is inserted in jack and twist of wrist locks connection. Manufacturer claims that it cannot work loose or accidentally pull apart. Fiber insulating sleeves afford protection against grounding. The Lincoln Electric Co., Cleveland.

Belt

Called "U. S. Royal Cord Belt." For all belt-transmission applications. Square-cut edges. Cords imbedded in rubber; single ply of duck on each side. Widths up to 24 in., plies from 5 up. United States Rubber Products, 1790 Broadway, New York.



Motor

With variable speed, and local or remote control. Called "U. S. Varidrive." Upright design. Take-off shaft in either high or low position. Horizontal design also available for applications where overhead space is limited. U. S. Electrical Mfg. Co., 1549 South Western Ave., Chicago.

Diesel-Starting Unit

Combination engine and single-stage compressor for starting gas and diesel engines. Runs on gas or gasoline. One-gallon gasoline tank mounted over compressor. Power and compressor cylinders, cast in one piece, are water-jacketed. Automotive type power-cylinder head and carburetor. Rotary-type magnets with impulse coupling for hand starting. Type GX3A. The Cooper-Bessemer Corp., Mount Vernon, Ohio.

Railings

All-steel, all-welded, jointless-post, railings. Flanges are attached to posts by concealed welds which are made in recesses in flanged bottoms. Flanges applicable to any angle from 0-70 deg. Cut to specifications at factory. The Fabricated Steel Products Co., 365 Marshall St., Wheeling, W. Va.

Shears

Line of foot-operated shears for cutting 16-gage metal. Cast iron housing. Steel holddown operated manually by self-locking eccentrics. Steel crosshead moves in flat ways with adjustable gibs. Back gage can be adjusted without use of wrenches. On 96- and 120-in. length shears a parallel-screw, adjustable back gage is used, by means of which adjustments can be made from either end of machine. Treadle mechanism has large tubular cross member resisting torsion or twist; thus assuring equal motion of both ends of crosshead. Back, front, side, and bevel gages. Knives available in 36-72 in. cutting lengths. Shears in 8- and 10-ft. lengths also available for 18-gage metal. Series F. Niagara Machine & Tool Works, 637-697 Northland Ave., Buffalo, N. Y.

Storage Battery

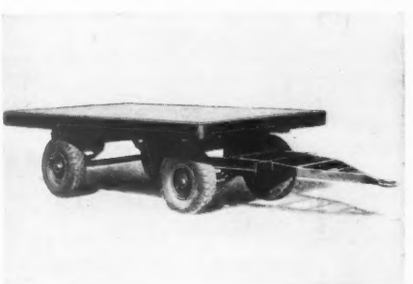
Called "KMD Kathanode Glassklad Cell." Highly porous laminated mats of finely spun glass retain active material in base structure. Low rib height. Base structure height 9⅜ in. Separators are combination of silica gel and finely divided particles of rubber. Large vent plugs, easily removed, have baffles and are so vented that electrolyte cannot spray over top of cell. Jar and cover are hard rubber of high tensile strength. For trucks and tractors. Designed to meet high current demands of starting, ramp operation, and excess loading. Gould Storage Battery Corp., Depew, N. Y.

Sanitary Equipment

The Ebco Mfg. Co., 401 West Town St., Columbus, Ohio, has purchased all assets of the D. A. Ebinger Sanitary Mfg. Co. Line of products includes drinking fountains, circular wash sinks, metal toilet partitions and shower inclosures.

Trailer

Spring-suspended, pneumatic-tired trailer of 4,000 lb. capacity. Hardwood deck, 26 in. above floor when unloaded, is set in heavy T-iron frame 60 in. wide and 108 in. long, reinforced with Z-iron longitudinal sills. Automotive-type, semi-elliptic springs mounted on one solid and one sliding shackle. Roller bearings. Six ply tires, size 6x9. Sixty-inch loop handle hitch. Clevis



coupler set back under frame to permit pushing of trailer from rear. The Mercury Mfg. Co., 4118 South Halsted St., Chicago.

Contactor

Magnetic a.c. contactor for built-in use. Capacities of 100, 150, and 300 amp. Built of aluminum alloy. Manu-

facturer claims cushioned closing slam. Self-lubricating, self-aligning ball bearings. Arc is immediately removed from contacts, as soon as they start to separate. Single, double, and triple pole. For continuous operation on 110, 220, 440, or 550 volts, 25 or 60 cycles. Called "LTZ Line-Arc." The Electric Controller & Mfg. Co., Cleveland.

Thread Gage

Model 897 Roller Type. Pitch diameter checked by inserting screws, bolts, and taps between interchangeable rollers. Gage set by adjusting screws on lower slide. Upper roller mounted independently of indicator point to eliminate strain. Model 19 indicator with 0-1-in. range and graduated to 0.0005 in. Dimensions of instrument 8¾x5x7¼ in.; weight 18 lb. Federal Products Corp., 1144 Eddy St., Providence, R. I.

Barrel Racks

Called "Knock-down Racks." Steel construction set up without bolts. Upright cross frames welded at factory; longitudinal members upon which barrels rest fit into oblique slots in cross angles of frames. Frames are interchangeable. Racks can be made any length desired, and are not permanently fastened to floor. Will accommodate containers of barrel size up to 500 lb. and containers of half barrel size up to 225 lb. Maryland Metal Building Co., Baltimore.

Unit Heater

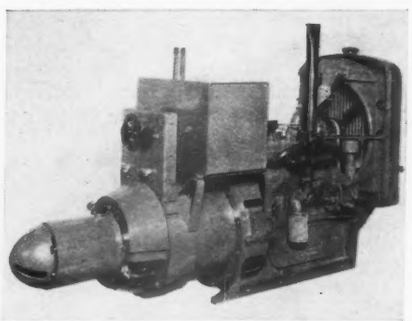
Gas-operated. Floor or suspended types. May be automatically controlled. Has safety devices. Aluminum heat exchanger. Heated air delivered horizontally near floor level. Cabinet finished in dark krinkle brown enamel. Known as "Floorflo Heater." The Trane Co., La Crosse, Wis.

Valve

Known as List 960. Machined from solid steel bar stock. Made in all standard sizes from ¼-2 in. For all services up to 600 lb. pressure at 800 deg. F. Sizes ¼-1 in. are designed for cold working pressures up to 2,500 lb.; larger sizes for 1,500 lb. Renewable stainless steel stem, plug, and seat rings. Can be repacked under pressure. Manufactured in monel, stainless steel, and other alloys for extreme corrosive service. The Chapman Valve Mfg. Co., Indian Orchard, Mass.

Welder

Called "200 Ampere Shield Arc Special." For welding with bare or heavily coated electrodes in sizes up to ¼ in. Welding current range 60-250 amp. Generator is single-operator, variable-voltage type with completely laminated magnetic circuit and equipped with interpoles. Requires no external reactance or stabilizer. Dual control of welding current provided by adjustment of both series and shunt fields. Separate excitation of shunt fields supplied by exciter connected on generator end of unit. Generator field rheostat and current regulating switch are mounted in vertical position on front steel control panel. Powered by Waukesha 4-cylinder engine delivering 23 hp. at 1,400 r.p.m. Gear-driven governor. Gasoline tank of capacity for full day's operation is mounted over generator. Engine direct connected to generator shaft. Unit weighs 1,078 lb. The Lincoln Electric Co., Cleveland.



Steel Grill

Protective device for doors and windows can be quickly raised or lowered when permanently installed and accurately counterbalanced with a helical spring. Can be locked when closed. Constructed of round steel bars connected by ornamental pressed steel links. Spaces are small enough to block entrance of a man's hand. Grill coils on heavy spiral above doorway or window and travels on guides mounted on sides of the opening. Can be built in any size and operated manually or mechanically. Kinnear Mfg. Co., Columbus, Ohio.

Extinguisher Accessory

Fire extinguisher hanger which automatically indicates when extinguisher needs refilling. When weight of extinguisher becomes too low, target marked "Fully Charged" drops and a "Recharge" target shows. Operation depends upon heavy spring coil with rod and pin connection to suspend target. Available for all Lux portable models of 10, 15, or 20 lb. gas capacity. Walter Kidde & Co., Bloomfield, N. J.

Testing Instruments

Line of lightweight, portable volt-ohmmeters and test units. D'Arsonval movement and switches for range selection. Single ohmmeter, volt-ohmmeter, and d.c. test units; multi-scale a.c.-d.c. test units. Scale length 2.4 in. Accuracy within 2 per cent for d.c. volts and milliamperes and within 5 per cent for a.c. Dimensions of case 7x4x3¼. Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa.

Elevator Cable

Fireproof elevator control cable. Resistant to moisture, oil, and corrosive vapors. Furnished any length and with any number of conductors up to 37. In construction, copper strands are coated with flame-resisting, waterproof rubber. Felt asbestos is applied over the rubber insulation and the conductors are bound together with fire-resisting filler. The cable is then bound with rubberized tape, and is finished with reinforced asbestos-yarn braid which has been saturated with a flameproof and moisture-resisting compound. General Electric Co., Schenectady, N. Y.

Switches

Type "A" Dualbreak safety switches of Colt-Noark line. Mounted in weatherproof cast iron cabinets. Built to

stand up under extreme operating conditions. Covers bolted to cabinet with non-corroding eyebolts. Rubber gasket between cover and case. Handle can be locked in "off" position. Rated up to 50 hp.; available fused or non-fused. Colt's Patent Fire Arms Mfg. Co., Hartford, Conn.

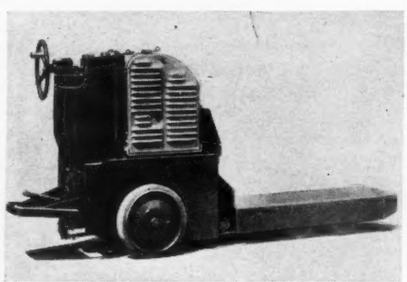
Welding Timers

Line of electro-mechanical timers for spot welding machines. Consists of electronic timing element and set of balanced contactors capable of handling overloads encountered in spot welding. Settings can be made for any time between 1 and 30 cycles. Timing accuracy of less than ¼ cycle is claimed at 1 cycle operation, within 2 per cent between 20 and 30 cycles. Sizes 30, 50, 150, 250, and 600 amp. Called Welco Timers. Welding Timer Corp., Chrysler Bldg., New York.

Lighting Fixtures

For use with 400-watt high intensity mercury lamp. High mounting reflectors made from aluminum sheet. Mogul-type skeleton socket held in place by cast brass adapter which is locked to reflector by cast aluminum cap. For ½-in. conduit mounting. Outside surface has one coat of glossy green baked enamel. Reflecting surface is acid etched. For low mounting, 24-in. High Intensity Glassteel Diffusers are available. Fixtures are drawn from Armco iron and finished with one ground coat and two white coats of porcelain enamel inside and outside. Same socket and holding construction as aluminum reflectors. Globe is of Monax single layer glass with copper globe-protecting ring. Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa.

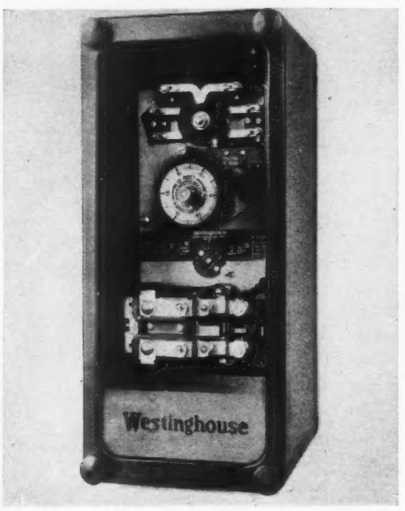
Truck



Low lift. Capacity 10,000 lb. Platform elevation by hydraulically operated link mechanism. Tandem trail axle employing four wheels, brakes in drive wheels, magnetic contactor control of travel and hoist, automatic overload protection, vertically or horizontally mounted steering wheel. Gas-electric or storage battery operation. The Mercury Mfg. Co., 4100 South Halsted St., Chicago.

Recloser

Motor-operated timing recloser with integrating lockout device for automatically reclosing a.c. or d.c. electrically operated breakers on a.c. systems. Set of cams, driven by synchronous motor, and two self-contained auxiliary elements provide initial immediate or delayed reclosure and several subsequent timed reclosures with reset if breaker stays in and lock-



out if it fails to stay in. Integrating lockout can be set for any number of reclosures up to 16. After lockout has operated breaker is locked out of service for inspection and whatever maintenance is needed. Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa.

Lathe

Known as "Workshop" 9-in. precision lathe. New model featuring 10 improvements. Included are twin gear reverse for cutting right and left hand screw threads of 4-40 per in., countershaft of either double friction type or horizontal type with either plain or adjustable belt tension, improved back-geared headstock with large spindle bearing and ball bearing thrust collar on spindle. Bed is one piece casting of steel and nickel iron composition and comes in lengths of 3, 3½, 4, and 4½ ft. with distances between centers of 17, 23, 29, and 35 in. respectively. Metal of all kinds can be machined. Six spindle speeds from 39-630 r.p.m. Optional is four-stage cone headstock for V-belt drive providing 8 spindle speeds. Complete set of attachments for handling wide variety of work can be fitted to lathe. Eight models in bench and floor leg styles. South Bend Lathe Works, South Bend, Ind.

Ball Bearing

Completely inclosed, cartridge-type, single-row unit. One row of balls. Inner and outer rings of standard double-row width to provide large grease capacity and prevent looseness of either shaft or housing. Metal seals are held firmly in place by snap-rings on outer race. Seals have long inwardly projecting flange with close running fit over grooved and recessed inner ring. Sealing plates can easily be removed for inspecting or cleaning bearing. Furnished with or without filling plug for renewal of grease. Can also be furnished with or without snap-ring on outer race. Made chiefly in medium series starting at 25 mm. bore. Known as "3000" series. Norma-Hoffman Bearings Corp., Stamford, Conn.

Expansion Joint

Packless. Known as U-Ring Type. Expansion element is series of die-formed U-rings of stainless alloy steel welded together without transverse seams. One end is welded to wrought steel body of joint and opposite end is welded to a plate that is in turn welded to the sleeve. Installed with expansion element compressed so that element is in neutral position when under maximum line pressure. Control rings and stop bolts distribute movement. Normal range of traverse 1-8 in. For pressures up to 400 lb., temperatures to 800 deg. F. Flanged or beveled ends. With or without anchor base. American District Steam Co., North Tonawanda, N. Y.

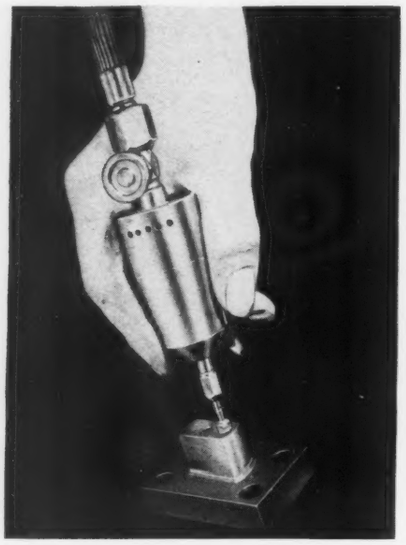
Valve Controller

Precision-valve-action unit applicable to any diaphragm valve and used in conjunction with any air-operated controller. For processes having time lags or heat capacities demanding low or medium controlled sensitivity. Unit is mounted on valve with direct, rigid connection to valve stem. Air or gas supply of 25 lb. per sq.in. used. Dimensions 8x5x2 in. Non-corrosive case and cover. Only adjustment is to adapt mechanism to full travel of valve stem. Indicator shows actual

percentage of valve opening. Called "Valve-Precisor." Taylor Instrument Cos., Rochester, N. Y.

Grinder

Called "M. B. Super Speed Air Grinder." Develops approximately 100,000 r.p.m. Is 5 in. long; weighs 8½ oz.



Constructed of aluminum and high grade steel. Shaft revolves on ball bearings. Self cleaning. Monnier Bros., Inc., Algonac, Mich.

Plating Anodes

Ball anodes for copper, brass, and zinc plating. Balls are placed in holder towards the bottom of which they drop as they corrode. New balls can be added continually, keeping anode with approximately same surface area. Balls available in pure electrolytic copper, pure or alloy zinc, and 80-20 brass. The Udylite Co., Detroit.

Grinder

Bench and pedestal grinder using 12x2-in. wheels. Heavy duty, totally inclosed motor, either 2 or 3 hp. Exhaust type, hinged guards. Adjustable tool rest which can be tilted for angle grinding. Heavy wide-base pedestal. Equipment includes waterpot, tool trays, and starter. Baldor Electric Co., 4351-63 Duncan Ave., St. Louis.

Welder

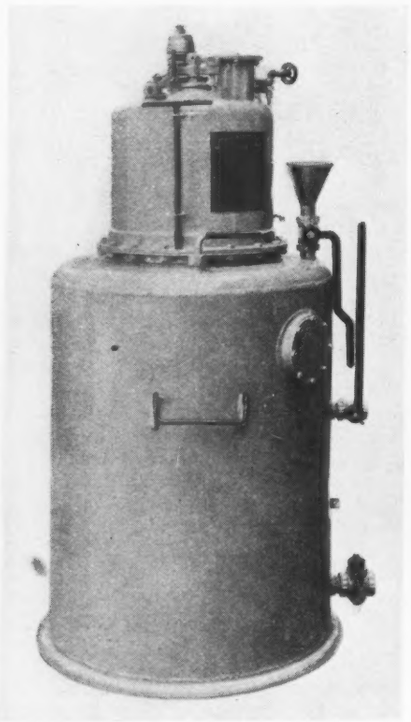
Single dial preset control. Open circuit voltage below hazardous range. Uses bare, dust-coated, or heavily coated electrodes. Magnetic control, utilizing magnetic shunt in armature reaction flux path, gives mechanical control, eliminating need for field rheostat, exciter, and external reactor. Output current adjusted by means of iron damper plates operated by the single control. Driven motor is of squirrel-cage induction type; 220 and 440 volts. Circuit breaker mounted within welder frame. For portable mounting 3-wheel design is used. Called "Flexarc." Westinghouse Electric & Mfg. Co., East Pittsburgh.

Grounding Equipment

One box for fixture mounting and three grounding fittings. Box, designated as Type SP-5200B, makes possible firm mechanical and electrical connection between box and armor. Two fittings, designated as Types SP-825 and SP-826, are intended for ½- and ¾-in. conduit respectively. They are equipped with reversible shackle that fits three sizes of water pipe. Type SP-828 has connection that grips and holds armored cable. Soldered or solderless connections can be made. General Electric Co., Schenectady, N. Y.

Acetylene Generator

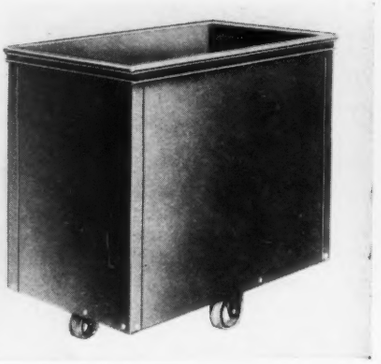
Known as Oxweld Type MP-6 Medium Pressure Generator. Has 50-lb. carbide capacity with double rating of 100 cu.ft. of acetylene per hr. For portable or stationary use with any type of oxyacetylene cutting or welding apparatus. Handwheel at top controls carbide feed so that acetylene at any desired pressure up to 14 lb. per sq.in. may be obtained. The Linde Air Products Co., 30 East 42d St., New York.



Loading Conveyor

Called "Selflo." Three lengths, 25, 30, and 35 ft. May be had with wheels or crawlers, gas or electric drive, gravity or vibrating screens, breaking bolt or automatic overload release, as belt or flight machine. Flights of ¼-in. pressed steel are connected to chain by swivel attachment links that compensate for uneven pull. Three-shaft transmission gives crowding and traveling speeds forward, two speeds reverse, two bucket line speeds, power raising and power lowering. Friction clutch for each crawler and one for main transmission. Hoist is automatically locked. Head end drive. Barber-Greene Co., Aurora, Ill.

Box Truck



Steel construction. Sides and ends of 20-gage sheet steel, bottom of 18-gage. Chassis of welded steel channels. Two 3-in. swivel and two 4-in. stationary casters. No rivets or bolts inside of truck. Rolled edges on top. Battleship gray, baked-on, synthetic enamel. Dimensions: 33 in. long, 19 in. wide, 24 in. deep. Stackbin Corp., Providence, R. I.

Tractors

Four diesel models with drawbar horsepower of 95, 61, 45, and 35. One spark ignition model called the "Thirty" has drawbar horsepower of 35. Overall height 5 ft. 5⅝ in. Caterpillar Tractor Co., Peoria, Ill.

Voltage Control

Adjuster for small alternators. Can be applied to a.c. generators varying from 5-250 kva. and 360-3,600 r.p.m. Solenoid operation, air dash pot damping and "rocking contact." Dimensions, 8¾x11x9⅜ in. Surface or bracket mounting. Known as "V1" Voltage Adjuster. Allis-Chalmers Mfg. Co., Milwaukee.

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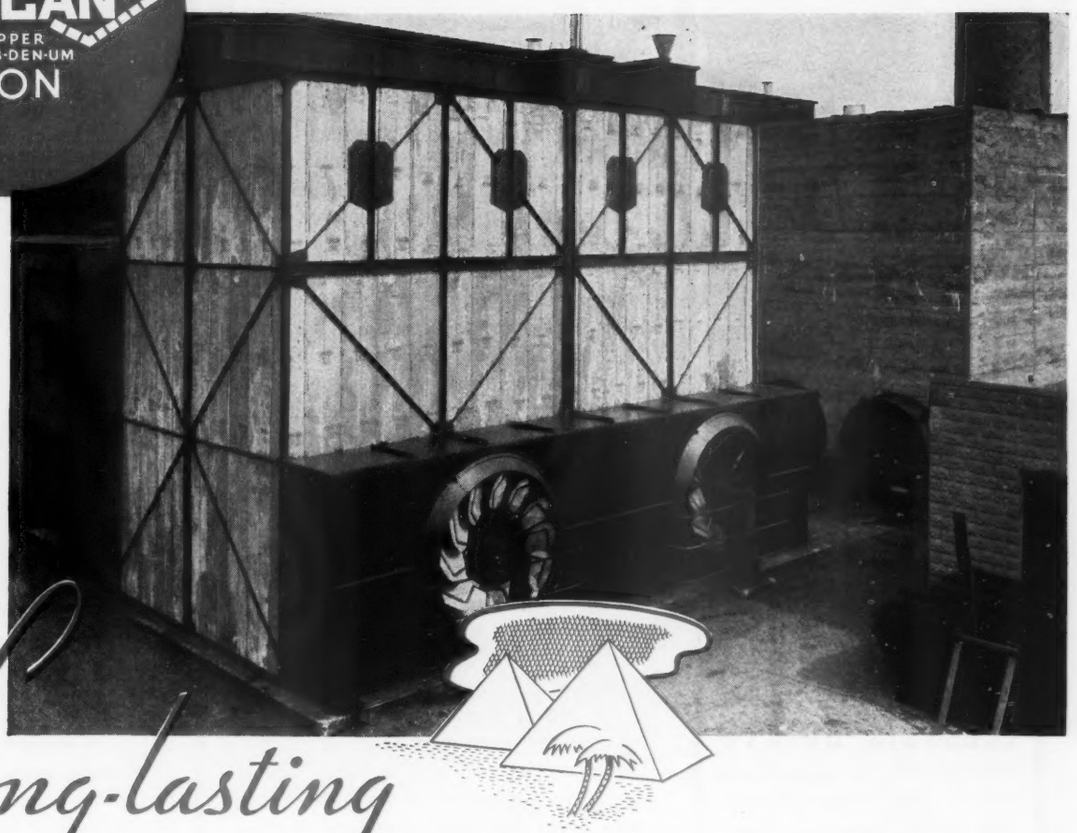
TRADE LITERATURE will be found on advertising page 52.

REG. U.S. PAT. OFF.
TONCAN
COPPER
MO-LYB-DEN-UM
IRON



Long-lasting

UNDER ADVERSE CONDITIONS

Sheet metal is a mighty handy material to have around. It safeguards life. It protects valuable equipment. It confines heat and cold and directs them to the point where they are needed. It serves a thousand uses, because it is so adaptable.

But don't neglect, when you are using it, to think about these things. You have paid good money for the metal itself. You are spending more money to fabricate it. You are using it to do a definite job, and you want it to last even under adverse conditions where weather, steam, moist air, chemical fumes or a combination of destroying forces will pick it to pieces.

Where such conditions exist, the logical answer is Toncan Iron—the alloy of refined open hearth iron, copper and molybdenum with the highest corrosion-resistance of any ferrous material in its price class—the sheet metal that is being used today in homes, factories and public buildings wherever long service and low yearly cost are given the consideration they deserve.

"The Path to Permanence" is a book that will interest you. Write for a copy.

Republic Steel
CORPORATION
GENERAL OFFICES · · · YOUNGSTOWN, OHIO

P&H ELECTRIC HOISTS

The handling of materials is just as much a part of your cost as the materials themselves. Move them more efficiently, perhaps stack them higher — to increase your profit margin.

Check your handling costs again. Even the slightest saving per lift may pay for your first hoist, or the change over of a misapplication to a high hook installation as illustrated. Frequently we find "push-on-the-load" types have outlived their usefulness and trolley drives are more profitable units to employ.

Ask us to send you a copy of Bulletin RH-2, which illustrates the right types of hoists for dozens of uses.

HARNISCHFEGER CORPORATION
Established 1884
4525 W. National Ave. Milwaukee, Wis.

P&H ELECTRIC HOISTS

Didn't Have to Build, Because —

(Continued from editorial page 505)

•

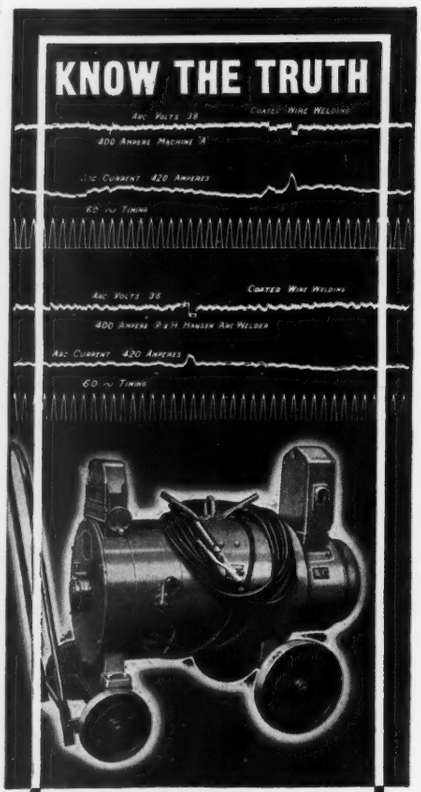
skid is because certain operations now have to be performed and they can be done more conveniently on the skid than on a conveyor. Also, the washing machine sets the pace and eliminates the danger of jamming along the skid. Kegs are inspected in the course of this 30-ft. roll. If a keg needs pitching, it is transferred to the pitch shop. Perfect kegs roll to the end of the skid, where bung corks are inserted, and moved right aboard Conveyor No. 5, which is again the single-strand type and travels at right angles to the skid in order to effect an automatic transfer of kegs.

That happens to be in the wrong direction, so almost immediately No. 5 makes a right-angle turn, moves horizontally for a short distance, then heads downhill (turn again to the elevation) into Cellar A and on toward the rackers. Figure 3 shows the junction point of Conveyor No. 5 and skid, shows No. 5 making the turn and heading off in the direction of the cellar. Incidentally, Conveyor No. 5 handles kegs down this 15-degree grade without ever losing a "passenger," and without any cleats or attachments on the chain.

Now to Fill the Kegs

Kegs have now reached the racking or filling machines. One is a 4-arm, the other a 3-arm machine. As each keg arrives, it is lifted off and placed under one of the arms. Seven kegs are thus accommodated at one time. Conveyor speed is therefore synchronized with filling time, to prevent any possibility of jamming. However, the conveyor chain is so designed as to permit an accumulation of kegs without the necessity of shutting off the mechanism.

From the racking machines, our main-line conveyor now splits up into two branch lines, each composed of a single-strand conveyor (Nos. 6 and 9), a short skid section (Nos. 7 and 10), and a rigid-arm elevating conveyor (Nos. 8 and 11). Reason for two branches is to split up filled-keg storage area and to facilitate the storing of different kinds of



about P&H-Hansen's UNIFORM WELDING CURRENT

The oscillograph record is the final court of appeals for arc welder performance. When you want the truth, ask for the record of this delicate instrument which plays no favorites—which detects every variation in voltage and amperage.

Ask for the record of a P&H-Hansen. Compare it with others. P&H-Hansen generators need no external resistors, reactors or stabilizers because uniform current is "built in". It gives you uniform flow of weld metal, uniform penetration of heat, uniform strength of welds. Operation is further simplified with single current control over the entire welding range.

Investigate! There's a new edition of Bulletin "Weld It Well". Write today for your copy.

HARNISCHFEGER CORPORATION
Established 1884
4525 W. National Ave. Milwaukee, Wis.

P&H HANSEN ARC WELDERS

Thank You!

1935 A BIGGER AND BETTER YEAR

Herman L. Krouse FORT WAYNE
C. E. Crandall NEW YORK
D. J. Wheeler DETROIT
Tom Sloan CHICAGO
J. A. Erlich LOUISVILLE
M. R. Hoyt BUFFALO
R. J. Koch ITHACA
H. Stevenson PITTSBURGH
Fred M. Botzato CHICAGO
W. F. Weston CINNATI
Charles L.
Quintin J. Keaney PHILADELPHIA
BOSTON
Thos. M. Marsley ITHACA
C. A. Shetler CLEVELAND
Grace E. Olmstead NEW YORK
F. Gunderson BOSTON
W. W. Bertram ITHACA
Carl C. Cross CHICAGO
Joseph A. Meaney PHILADELPHIA
H. E. Lunn Jr. NEW YORK

It's been a great year for Morse. Thousands of customers, both new and old, have given Morse a generous share of their business during 1935. Throughout industry there has been a definite upturn in business—plants are being modernized, definite savings are being made in production costs and Morse is endeavoring to meet these demands through careful, considerate service to industry.

Morse is also keeping pace with modernization with new equipment at both Ithaca and Detroit plants. These increased facilities assure Morse customers of better service in manufacturing and delivery.

Morse takes this opportunity to thank industry for making 1935 a bigger and better year, and also to show its appreciation of the sincere and earnest efforts of these Morse men in the field. With thorough knowledge and experience in transmission of power, they are always ready to serve industry with better methods of power transmission.

MORSE

Silent and Roller Chains and Sprockets
Flexible Couplings and Clutches

Morse Magic Silent Chain Drive Selector automatically selects the proper drive, checks and designs chain drives, saves time. Send for one. It's free.

Morse 1936 Calendars are now ready. Ask for your copy.

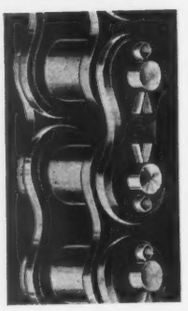
MORSE CHAIN CO., ITHACA, N. Y.
Division of Borg-Warner Corporation

. . . is BALDWIN-DUCKWORTH on your ticket?

Baldwin-Duckworth roller chain helps these chaps to be Johnny-on-the-spot in case of trouble, for it's standard equipment on every American made motorcycle, and has been for many years.

HARLEY-DAVIDSON

Indian

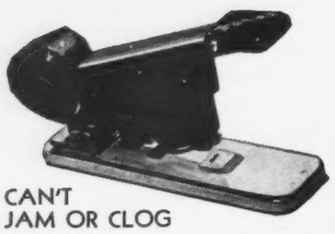


AND FOR INDUSTRIAL DRIVES

For every manufacturer too, it's a positive guarantee of reliable performance, accuracy, and real economy on any power transmission or conveying job. Get complete information by sending for catalog showing all sizes of single and multiple chains, attachments, sprockets and engineering data covering their correct use. Baldwin-Duckworth Chain Corporation, Springfield, Mass.

BALDWIN-DUCKWORTH

FREE 10 DAY TRIAL



CAN'T JAM OR CLOG

BATES STAPLER

Makes its own staples. 5000 in one loading

For free trial, without obligation or expense, simply return this advertisement attached to your business letterhead.

DEPT. L-3

The BATES MFG. CO., 30 Vesey St., New York

MAKERS OF BATES NUMBERING MACHINES

PHENOL FIBRE
MICA
FISH PAPER
BAKELITE
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DON'T GUESS!
Ask Insulation Headquarters—
CONTINENTAL-DIAMOND
No matter what your insulation problem may be we should be able to help you. We manufacture all forms of laminated insulation—DIAMOND FIBRE—DILECTO—CELORON — VULCOID — CELLULAK — CODITE — therefore our recommendations will be without prejudice.
Write us for specific information — or for catalogs
Continental-Diamond Fibre Co.
NEWARK, DELAWARE

beer. The racking machines can discharge to either one of these branches by adjusting the telescopic skid shown in Figure 5 which shows filled kegs moving from the rackers. Labels and revenue stamps are affixed en route. Kegs may be stored or moved direct to the shipping platform. Here again an automatic count is made. One of the rigid-arm elevating conveyors (No. 8) is shown in the photograph on page 503.

Right now the system serves only one washer and two rackers. It can, however, be speeded up to take care of another washer and additional rackers, if they become necessary.

The system has been in service long enough for us to know that it has materially improved operating conditions and has helped us increase kegging capacity in a limited space. Handling costs are nothing like they used to be. There is no more lost motion and congestion. Manual handling has been reduced to the bare minimum. And, more important than all, we have been able to better our deliveries to customers. The over-all improvement in kegging operations has certainly justified the investment several times over.

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Quality Under the Thumb

(Continued from editorial page 509)

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until the defect disapears or until a satisfactory reason is presented.

He has two aids. One is a system of speaking tubes which affords direct, instant, and easy communication with the operators downstairs. He could report in person to the operators, chief operator, or the shift foreman, but a simple and convenient means of communication actually at his elbow tends to overcome that feeling to "put it off." By making it as easy as possible for the men to do the little things, we insure their getting them done at once and in the right manner.

Second aid to the inspector is a group of colored lights above each machine and under his sole control. These lights are used to stimulate the machine operators to action. Each color represents a certain defect and is switched on as soon as the defect appears and stays on until it is cleared up. As the lamps are in plain sight of everyone in the fac-

The trials of the Great *A. Bu Sed*

(A TOUGH CASE)

WITH MY COLORGRAPH REINFORCEMENT I MAKE YOUR SHIPPING CONTAINERS OUTSTANDINGLY ATTRACTIVE AS WELL AS ADEQUATELY SECURE. LET ME PROVE IT, A. Bu Sed
A. Bu Sed WELCOMES ALL SKEPTICS
ROUGH HANDLING HOLDS NO TERRORS. LESS FORTUNATE IS THE UNPROTECTED CONTAINER.
PILFERAGE IS OUT. THIEVES PASS HIM UP FOR THE EASY MARKS.
QUICK IDENTIFICATION WITH COLORGRAPH INCREASES CUSTOMER GOODWILL.
LIGHTER WEIGHT CONTAINERS REINFORCED WITH COLORGRAPH OR ORDINARY BLACK STRAPPING COST 20% TO 40% LESS THAN HEAVY CASES.
YOUR OWN PRIVATE BRAND OF STANLEY COLORGRAPH IS TODAY'S OUTSTANDING CONTRIBUTION TO BETTER, SAFER, MORE ATTRACTIVE PACKING.

Those shippers who use heavy, unprotected shipping containers can make substantial savings through the use of lighter weight containers reinforced with Stanley *Private Brand* Colorgraph and at the same time greatly reduce loss and damage.

Shippers who are now using ordinary steel strapping and know its advantages will be quick to appreciate the several real advantages offered by Stanley COLORGRAPH *Private Brand* Steel Strapping.

We shall be glad to send samples and further information.

FOR EFFECTIVE ADVERTISING, ATTRACTIVE CASES AND FREEDOM FROM PILFERAGE USE STANLEY COLORGRAPH STEEL STRAPPING

THE STANLEY WORKS

STEEL STRAPPING DIVISION

159 Lake St., New Britain, Conn.

NEW YORK
100 LAFAYETTE ST.

CHICAGO
62 W. KINZIE ST.

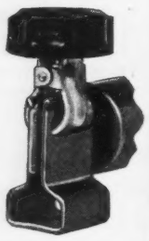
This is a sample of COLORGRAPH STEEL STRAPPING which can be furnished in any design and almost any color combination

TRICO
REG. U. S. PAT. OFF.
PRODUCTS
will help you maintain plant capacity
OPTO-MATIC
CONSTANT LEVEL
OILER

For ring, ball and wick type bearings.
Saves oil.....
Saves time.....
Ends troubles and burnouts .....
(Send for literature)

KLIPLOK
REG. U.S. PAT. OFF.
CLAMPS
for FUSE CLIPS

Eliminates burnt fuses and clips.
Reduces blow-outs...
Reduces Watt Loss...
Made in all sizes.



FUSE
PULLERS
"A lifetime of Safety First Service"
Made in 4 sizes

Write for literature
TRICO FUSE MFG. CO.
Department F
Milwaukee, Wisconsin

tory, from the occasional visitor to the general manager, the chief machine operator and the operator of the machine at fault hustle in order to get the telltale light out of sight.

Few operators are content to go through a shift without fighting to put out any colored light that may be turned on above their machines. Even though the defect may be caused by a general furnace condition beyond the operator's responsibility, he will so manipulate his machine as to minimize the bad effects of the incorrect condition.

Cutters working at piece rates grade the glass to rigid specifications, cut it into the various sizes, and set it outside their stalls. It is the quality output of these cutters that it is so important to keep constant. One of a group of expert inspectors therefore makes an occasional unexpected visit to each cutter's stall to inspect every piece of glass he has put out on that day. These inspections are thorough and from "AA" quality down to "steel sash."

This checks the general factory output. All high-quality glass is inspected piece by piece, as are orders that are packed for government jobs, railroad companies, and some of the automobile and mirror people.

Keeps Customers Happy

During the night (the glass cut one day is packed the following morning) another inspector checks over all the glass to make certain that it is of the correct thickness, size, quantity, and label called for on the order.

This inspection is important from a customer viewpoint. Besides checking on the cutters, it is a last-minute elimination of those little mistakes that customers are quick to seize upon and make the subject of complaints. Shortages and fractionally off-size glass are sure breeders of lost customers.

Incidentally, every box is plainly dated and stamped with the number of the cutter, inspector, and packer. Tracing back the origin for complaints is quick and effective.

This practice of careful inspection has resulted in the fact that quality labels on domestic produced flat glass are recognized and accepted at face value. Unvarying qualities mean dependability of brand and consequently attractiveness to the market.

JOHNSON
ATMOSPHERIC
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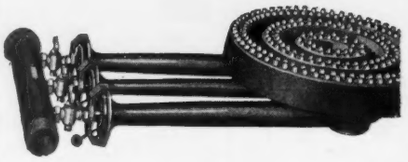

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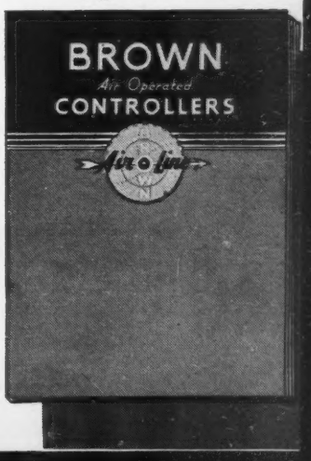

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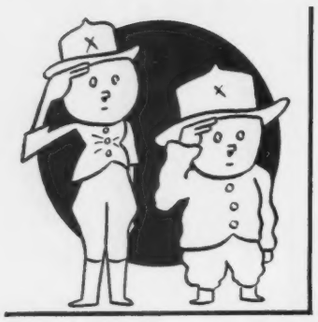

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To Keep Small A.C. Motors Going

(Continued from editorial page 516)

Ball bearings usually become noisy and require replacement before the air gap is impaired to any extent.

As a motor comes up to operating temperature, the shaft elongates slightly. The manufacturer usually allows about 1/16-in. play to avoid end thrust on the bearings from this cause, and provides thrust washers for minor adjustments. Provision is also made for the thrust caused by the strong magnetic pull tending to center the rotor in the stator along the line of the shaft axis; motors are adjusted so that this force acts to keep the rotor within the end-play clearance at full-load torque and speed.

Collector rings of wound-rotor motors should present a smooth, polished surface to the brushes at all times. If oxidized, grooved, or pitted, fine sandpaper applied with a block shaped to fit the collector will usually restore the surface to good condition. Canvas applied in the same manner is an excellent polishing agent.

The rings should also run true; that is, they should be concentric with the shaft.

Brushes should always make good contact with collector rings. Spring pressures on the brushes should be approximately equal. Discard brushes when they become too short to fit the holders; placing blocks between the spring and brush only invites chattering.

When frames come from the factory, they are painted or enameled to resist corrosion and mechanical injury, and to improve their appearance. An open motor should not be washed with a hose since water will enter the windings; washing should be done with a cloth, being careful that water does not drip into the windings. Grease and dirt not dissolved by washing should be removed with a good solvent, and corroded or rusted places cleaned up.

A motor having a clean, well-kept appearance may not be in perfect condition electrically or mechanically, but it usually indicates that the maintenance department is taking pride in its work and that, in all probability, inspection and maintenance work has been carefully done.

Factory Management and Maintenance
Plant Operation Library

FOREMAN TRAINING

1. For large plants that have enough supervisors and foremen to make up one or more conference groups.
2. For small plants that do not have enough supervisors and foremen to make up training groups of their own and must therefore work with other plants in setting up a plan.
3. For individual supervisors and foremen who are denied the advantages of formal training and must therefore train themselves.

WHO IS THIS FOREMAN that needs to be trained? He's the man on the firing line. He's the man between the management and the men. He represents the management to the men, the men to the management. His title may be foreman. It may be supervisor, overseer, "gang leader," "boss." He may have no title at all.

Whatever he is called—and for convenience we shall refer to him in this booklet as foreman, occasionally as supervisor—he is the man who has to show results. Squarely on him rests the major responsibility for production.

He must be familiar with physical equipment and the "how" of his job. He must know more about the "why" of his job. He must know men. He must be a leader. He must be a teacher. For every industry, large or small, the first step toward better management is the training of these minor executives—these supervisors, overseers, "bosses," foreladies, foremen.

You might expect foreman training to be as old as scientific management itself. It's not. It's relatively new. Twenty years ago it was almost nil.

The War came along and changed all that. The ranks of industry were quickly depleted. Green workers had to be inducted into service. Skilled workmen were drafted overnight into supervisory positions.

These men had to be trained. They had to be trained quickly. Training plans were hastily thrown together. Some were good. Many were bad. No matter, industry had found an invaluable tool, began to use it.

Today, as regards the number of plans in active operation, industry is about where it was in the early years of the war. Many a good plan went by the board during the depression, some because there wasn't the money to carry them on, others because there weren't enough foremen left to train.

However, in a much more important respect industry is far ahead of where it was twenty years ago. It knows and appreciates the value of training plans. It has profited by some of the mistakes it made during the War and post-War years.

It does not have to be told that, more than anything else, it needs good foremen. It does not have to be told that the rapidly changing industrial scene has brought new conditions which yesterday's foreman, unless trained to meet them, cannot hope to cope with.

It is perhaps unfortunate for all concerned that there is no single procedure that can be followed out to the last jot and tittle. With industry set up as it is, we can probably never hope for such a break, either in training foremen or in any other phase of management activity.

However, in the absence of a single superplan to be used "as is" in any industry, we can always draw upon the successful experiences of others. A foreman training plan out of the aircraft industry, for instance, serves readily as a horse on which you can hang the clothes of your own industry. Don't forget that your industry and the aircraft industry are, under the skin, much like the Colonel's lady and Judy O'Grady. In other words, the fundamentals of management are always the same whether the product is ships, or shoes, or sealing wax, pretzels, pianos, or pins.

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All of which serves to explain why the editors of FACTORY have chosen to present in this booklet a complete foreman training plan. They know management doesn't have to be sold on the idea. They believe management *does* want to know exactly how to map out a program.

So, here it is. It happens to be the plan now in operation at the Douglas Aircraft Company, of Santa Monica, California. It has been selected as a typical example of an effective program that has stood the test of application. The plan was set up by a representative of the Bureau of Trade and Industrial Education of the California State Department of Education, in cooperation with the Douglas Factory Superintendent and Personnel Manager.

The Douglas plan is presented as a report of eight out of ten foreman conferences exactly as they were held. Only those details have been omitted that apply exclusively to aircraft manufacture. The same subjects discussed by Douglas foremen in these conferences may be made the basis for a conference type of foreman training plan in any plant where a set program of foreman training is needed.

Not all of the field of foreman training has been covered in the Douglas plan. No single plan can ever hope to cover the whole ground. But here are the principles. Here is a big start.

That is not all. To supplement the Douglas plan, the editors have added the outlines of plans now in active operation at General Motors Corporation, International Business Machines Corporation, The American Rolling Mill Company, and a well-known Eastern industrial concern. From these outlines the concern that is just starting a foreman training plan can see how the wheels are set in motion. Then, when it becomes necessary to plan new meetings, there is on the last page of this booklet a list of 145 typical topics to talk about. Help yourself.

A TESTED FOREMAN TRAINING PROGRAM

A plan that worked for the Douglas Aircraft Company, Santa Monica, California

CHAPTER I

Exploration and Planning

FIRST MEETING

THE CONFERENCE of supervisors was called to order by the Factory Superintendent. He introduced the conference leader and explained that the leader did not intend to tell the foremen how to do their work, but would take up specific problems and by means of conferences with the group would arrive at solutions. The Factory Superintendent specified that the conferences would serve three purposes:

(1) Enable the foremen to get together and freely express their opinions regarding suggestions for solving definite departmental problems.

(2) Help to establish a better understanding of relationship between the foremen and the company, and the foremen and the men.

(3) Develop methods for solving problems.

WHAT IS THE JOB OF A FOREMAN?

(Statement by Conference Leader)

A foreman is paid for having ability, *plus*. The *plus* has to do with handling men, developing efficiency, and organizing work.

We all recognize that as an industrial organization grows it requires additional operators and mechanics. It is impossible for the owners or the management personally to supervise and take care of all the men and all the work in an organization where a great many men are employed. The management, therefore, finds it necessary to rely on some men in its organization who will assume these responsibilities. The men to whom this work is delegated and who assume certain responsibilites are known as supervisors or foremen.

A foreman is not a person who is appointed for political or sentimental reasons. He is appointed because he has been successful and dependable in his work. He has been proficient in his job, and is promoted because he knows more than his job. He has developed abilities other than those of doing. Some of these are the ability to supervise, to handle men, and to organize work. A real foreman is a "gold mine" to the company and an indifferent foreman is worse than no foreman at all. A real foreman is the "key man" in industry.

In attempting to solve problems which confront the foremen of this organization, it is logical to assume that they have had a sufficient amount of practical experience and are sufficiently familiar with the company's policies to help them arrive at solutions to problems affecting their own departments.

FORTY THINGS A FOREMAN HAS TO DO

(Compiled by the Foremen)

The conference leader asked the group about some of the jobs that a foreman had to do, and the following list was compiled:

1. Instructs and trains men.
2. Disciplines men.
3. Looks out for the welfare of men.
4. Sees that the men do a day's work for a day's pay.
5. Checks the work of the men; eliminates mistakes.
6. Distributes work.
7. Meets schedule requirements.
8. Serves as a go-between with reference to the shop and the engineering department.
9. Cooperates with other foremen in other departments.
10. Maintains harmony with men in his own and other departments.
11. Keeps standard of workmanship high.

12. Places each man on the job he is best fitted for.
13. Plans his work.
14. Provides material for men.
15. Keeps up with new methods of production.
16. Develops new methods for the company.
17. Plans on the right number of men for the job.
18. Makes suggestions regarding designing new tools.
19. Gains the confidence of his men.
20. Gains the respect of his men.
21. Organizes for best production methods.
22. Controls himself at all times.
23. Estimates time required to do a job.
24. Delegates responsibility.
25. Recognizes and appreciates the ability of his men.
26. Cuts down overhead.
27. Cuts out waste of time and materials.
28. Understands methods in other departments.
29. Carries out the principles of the company.
30. Builds up the morale of his men.
31. Creates interest in work.
32. Corrects or stops erroneous rumors.
33. Represents the men to the company.
34. Represents the company to the men.
35. Gets loyalty of the men.
36. Gives favorable recognition for good work.
37. Keeps working conditions favorable for the men.
38. Makes constructive criticism.
39. Checks on safety-first with men and equipment.
40. Checks on the efficiency of machines.

WHAT THESE FORTY DUTIES SHOW

This list brings out quite clearly:

1. A foreman has a considerable amount of work to do with men.

2. A foreman has a considerable amount of work to do with work.

In other words, a foreman is tied up with *work jobs* and *man jobs;* therefore, all foremen must pay particular attention to *organizing work* and to *handling men.*

A FOREMAN IS AN EXECUTIVE

The foregoing list includes a great many jobs which affect organization, equipment, new ideas, new methods, time-keeping—jobs of an *executive* nature. Obviously we can organize the general duties and responsibilities of the foremen under the headings: Supervision, Instruction, Organization, in this way:

1. The Foreman Directs.
- He supervises the men in his department.
- He supervises the work in his department.
- He supervises the equipment in his department.
- He supervises general conditions in his department.

2. The Foreman Is an Instructor.
- He sees that new men are trained for jobs.
- He sees that "old hands" are trained for new jobs.
- He gives some training to all of his men.

3. The Foreman Is a Minor Executive.
- He represents the men to the company.
- He represents the company to the men.
- He represents the men to the men.
- He assumes responsibility for getting the work done in his department.
- He is concerned with efficiency in his department.
- He "puts over" the rules and regulations of the company to his men.

It is evident that a foreman plays a considerable part as a minor executive. He must assume certain responsibilities. He is particularly concerned with the depreciation of equipment and the overhead cost in his department. He is vitally concerned with the large amount of capital tied up in his department and with the idea that his department must pay if it is going to exist. Departments are very important parts of a big organization and each department must be efficient.

SUGGESTIONS FOR OTHER MEETINGS

Upon request the group suggested problems for later meetings; here they are:

1. Morale of workers.
2. Organization of work.
3. How to handle rush jobs.
4. How to cut down overhead expense.
5. Proper planning of work.
6. How to get equipment and tools required for a job.
7. Recognition of ability of men.
8. Personnel.
9. Time study.
10. Cooperation of departments.
11. Training of men.
12. Meeting schedules.

CONCLUSIONS

The conference leader recapitulated the thinking of the foremen at the first conference:

1. A good foreman is a "key man."

2. A foreman has many duties and responsibilities. They can be listed so that he will know what he is expected to do. As a foreman improves, the department improves.

3. A foreman is a minor executive, a director, and an instructor. He can organize his work by listing the jobs he does under each of these headings. This list can then serve as a work check for the foreman.

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CHAPTER II

Cooperation

SECOND MEETING

What is cooperation? Working together; correlating work in departments; getting things done with the least possible friction.

I work with you.
You work with me.
We work together in the interest of the company.
We work together for our own interest.

As long as large organizations exist there will be many different departments and many different kinds of workers. The foreman who cannot get along with his superiors, or with heads of other departments, or with men, is a serious drawback.

TYPES OF COOPERATION

Industrial organizations are concerned with *Vertical Cooperation* and *Horizontal Cooperation.*

VERTICAL COOPERATION

Sometimes it happens that orders must be issued from the superintendent's office direct to the assistant superintendent, who in turn gives them direct to the foreman of a certain department. The work in this instance involves only the work of one department and does not require the cooperation of other departments. This type of organization makes it

quite easy for a foreman to carry out his responsibilities. He is engaged in *vertical* cooperation.

HORIZONTAL COOPERATION

There are a great many departments in the Douglas Aircraft Company's plant. It is impossible for each department to work independently. If each were to do so, there would be confusion and inefficiency. Departments must also work with other departments. This type of organization requires *horizontal* cooperation. When industries are organized on this basis the foreman is expected to use initiative and brains in order to keep things moving.

KINDS OF COOPERATION

1. The kind of cooperation in which the foreman completes his own responsibility and quits. This is a weak kind of cooperation. Good foremen never work on this basis. It does not call for much initiative and does not give the foreman an opportunity to check up on things being made.

2. The kind of cooperation in which one foreman will help another foreman until help is no longer needed. This is the most important kind of cooperation. It brings out all the ability, initiative and brains that a foreman has. This type of cooperation brings out quite clearly that a foreman is concerned not only with the work in his own department but with the work in other departments.

SOLVING A PROBLEM IN COOPERATION

To serve as an illustrative case the conference group outlined the common problem of parts being tied up according to causes and suggestions for improvement:

PROBLEM: PARTS TIED UP

Possible Causes for Problem	*Suggestions for Solving Problem*
1. Tooling.	Take up with foreman of department before tool is designed; he may be able to offer suggestions.
2. Shop errors.	Better trained men, better supervision, and a closer check by foreman.
3. Engineering changes.	Speed up method of handling changes in engineering and shop departments.
4. Material shortage.	Cooperation between purchasing department and engineering department. More consideration of delivery dates.
5. Inspection.	Cut out unnecessary inspection. Set time limit on inspection.
6. Defective material.	No suggestions.
7. Transportation.	Better grouping of departments.
8. Lost parts.	Use metal bins. Have as little handling as possible. Let work be done by experienced hands.

HOW DEPARTMENTS CAN COOPERATE

After discussing this problem, the group listed these definite ways of obtaining better cooperation between departments:

1. Shop foreman should pay particular attention to the organization of the work in his department. Each foreman should insist on organizing the work in his own department so that all departments work together efficiently and without friction.
2. Production control department should get information to other departments ahead of time. Departments cannot always prepare definitely for what is coming; yet, if they know an order is coming through, it will enable them to do some advance planning.
3. Experimental department might be more efficient if it were entirely independent of other departments.
4. Keep shortage-chasers on same job.
5. Send blueprints to tooling group; then send drawings to be blueprinted; then have planning department issue shop orders.
6. Notify production control department immediately when it is impossible to complete parts.
7. Keep a closer check on time parts are in process.
8. More cooperation between foreman and stock-chaser.

WHAT THESE SUGGESTIONS MEAN

The foregoing list has to do with definite suggestions from the foremen regarding cooperation between departments. These suggestions are specific. They imply a necessity to follow certain suggestions regarding cooperation between departments:

Appreciate the work in other departments.

Appreciate the fact that the other departments have their own problems.

Show consideration for the other fellow.

Have a knowledge of the problem as a whole.

Be careful about criticizing the work in other departments.

Keep your own department above reproach.

Practice what you preach.

Be patient with others.

Do not carry grudges.

CONCLUSIONS

1. Foremen in all departments must pull together for the good of the company.

2. Foremen must give cooperation if they expect to receive it.

3. Foremen should get together and talk over problems affecting their work.

4. Foremen must have confidence in each other.

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CHAPTER III

Cooperation Between Departments (Cont'd)

THIRD MEETING

(Introduction by Conference Leader)

There are four ways in which to get something done with a group of men:

1. Sometimes a superintendent finds it necessary to call together his supervisors and explain certain policies regarding the company that they should know. In this case he is using the *Information Method* of getting something done. The men have been told something new.
2. Sometimes a superintendent issues direct orders regarding what he wants done. The superintendent is then using the *Order Method* of getting things done. He expects his foremen to follow the orders as given by him. The orders should be simple, clear, definite, complete.
3. At one of our other meetings we found that one of the jobs of a foreman was to give instructions. We call this the *Instructional Method* of getting something done.

A good example of this is where the foreman finds it necessary to instruct old hands regarding new methods.

4. Another very important way to get things done with a group of men is by use of the *Conference Method.* By this method a foreman can get his men together and help them think through their own problems and arrive at some definite conclusion for carrying on. In this case all the men have to get together, work together, think together, learn together.

All four methods are used in every industrial organization. It is up to the foreman in each department to use the method which best fits his case. At times orders are necessary, but in many cases more work can be accomplished with least friction by means of the conference method.

The group elected to consider another problem.

PROBLEM: HANDLING OF CHANGES

What Causes Trouble	*Suggestions for Improvement*
1. It often takes too long to get a change through.	Improve on methods for handling blueprints in various departments.
2. Sometimes changes are made without due notification to other departments involved.	There is need for keeping closer tab on and control of blueprints in various departments.
	There should be no changes in blueprints without a letter change.
	It might speed up production if, before making the change, some one would consult the department that will use the part.
	Before making a change the number of parts and tools should be considered.

Other problems were submitted for investigation:

PROBLEM: TYPE OF TOOLS

What Causes Trouble	*Suggestions for Improvement*
1. Sometimes it takes too long to produce the tool.	Production probably would speed up if more information were given on prints.
2. Sometimes too much time is spent on making tools.	It would be worth while to plan ahead of time for tools needed.
3. Often there is a lack of information on prints.	It would help production if the project engineer informed the departments concerned ahead of time.
	It would be worth while to standardize types of tools for same use everywhere.

PROBLEM: DISTRIBUTION OF WORK

An incomplete outline was used to get a picture of the distribution of work.

1. Engineering department to .....
2. Planning department to .....
   a. Manufacturing all the material as planned.
   b. Orders, if new, are routed through tool divisions.
   c. Blueprints are sent to tooling department in advance of planning.
   d. Blueprints are sent to manufacturing department at time of issuance of orders.
3. Material department and tooling department.
   a. Work is distributed from the planning department the material and tooling departments.
   b. Work is also distributed from tooling department to material department.

SUGGESTIONS FOR IMPROVEMENT OF DISTRIBUTION OF WORK

1. Advance copy of the blueprint might be sent to the tooling department immediately after engineering check.
2. On the parts where advance tooling is required the project engineer could furnish tooling department with advance prints.
3. Tool design and tool planning should be more closely coordinated with the engineering department.
4. The tool designer might function as a part of the engineering department.

It became evident that the cooperation of the engineering department was essential, and the group agreed to continue the discussion at the next meeting to which several representatives of the engineering department would be invited.

CONCLUSIONS

1. Industrial problems require the best kind of cooperation.

2. Problems may be handled by information, instruction, orders, conferences.

3. Intricate problems involving various departments are best solved by means of the conference method.

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CHAPTER IV

Cooperation Between Departments (Cont'd)

FOURTH MEETING

(Representatives from the engineering department present by request)

ENGINEERING DEPARTMENT SUGGESTIONS

1. Improvement in methods for handling blueprints would mean setting up a new system which might be rather expensive.
2. Blueprints are subject to changes. As the men work with the blueprints they are continually making suggestions regarding changes for improvement. This means that changes are being made continually.
3. Aircraft factory work is subject to a tremendous amount of rush work. This means that departments are rushed for time. Any elaborate system developed might have to be changed over night.
4. Engineering jobs often have revised parts in them. This requires tearing apart and reorganizing drawings.
5. There is at present a continual conference between the checker and the engineering department regarding parts before production work is carried on. This helps to speed up work.
6. It is most important that blueprints be checked before being sent to the various departments.

SUGGESTIONS FROM THE GROUP

1. There is need for getting the prints to the tool designer sooner.
2. There should be developed some systematic method for taking care of changes.
3. There is a need for advance information to other departments.
4. It might be worth while to have some one department responsible for tools needed.
5. Some scheme should be developed to give tooling department advance copies of drawings.
6. Jigs could be finished sooner if the tool designer worked closely with the engineering department. This would help to speed up production.
7. While there may be a considerable amount of trouble regarding the small equipment going through, work could be so planned that there would be very little trouble with big equipment. The larger equipment is very expensive

and takes a considerable amount of time in development; therefore it is important that advance information be given, that the work be done right in the beginning in the interest of conserving time and material.

CHANGES IN BLUEPRINTS WITHOUT A LETTER CHANGE

Another suggestion that had been made was that there should be no changes in blueprints without a letter change. This suggestion was considered at this time because it affected the engineering department. Representatives of the engineering department commented as follows:

1. No revisions or changes should be made unless print is marked up and signed. This is a matter of rule enforcement; however, sometimes revision is made without being signed. It was suggested that more attention be paid to seeing that this rule is followed closely.
2. Last reference print must carry the change.
3. When reference blueprint goes out of shop and it is found necessary to make a change, the print is handled the same as though it had been out in the shop for a year. The rule is to add letter when changed and also add date.
4. The old models required 6 rib drawings. New models would require almost 600 detail rib drawings.
5. The engineering department is concerned with the problems involved in saving weight.
6. The greater the rush the more reference prints needed.

FURTHER SUGGESTIONS FROM THE GROUP

1. It will pay to make more blueprints.
2. It will pay to make more templets.
3. The number of changes should be cut to a minimum.
4. The loft should play a more important part in helping the engineering department with some of its problems.
5. It is possible to spend too much time on experimental jobs and make too many changes in a new job.
6. Print may go through experiments and changes and no reference of change noted.
7. There should be a shop record of reference prints.
8. The engineering department should keep an accurate record of reference prints.

The group next decided to make a general outline so as to get a better picture of the problem.

PROBLEM: ISSUING BLUEPRINTS TO TOOL DEPARTMENT AFTER CHECKING

Questions Raised by the Group	*Answers Given by Members of the Engineering Department*
1. Why not send out prints in advance?	This would require a new set-up in the engineering department. There is a question in the minds of the members of the engineering department that this would be a paying proposition.
	Aircraft factory work is very complicated. There is a question whether a new set-up would be less or more complicated.
2. Would it be worth while attempting a new set-up?	It would mean running every job (related drawings) twice.
	It would mean a 50 per cent increase in time in the blueprint department.
	It would delay delivery to planning department.
3. Why not blueprint before bill of material, weights, and release sheets?	The job cannot go to planning department without release sheets. It would seriously complicate the present set-up.

The group suggested:*

It would be worth while to plan a set-up which would get prints out in shorter time.

There is a possibility of gaining five days in designating the tool.

A considerable amount of time now spent looking for blueprints might be saved.

Improve method of supplying tool department with drawings by tool design department.

Five days are sufficient to complete small tools and templets in many cases.

CHANGES* RESULTING FROM CONFERENCES

Members of the engineering department stated that as a result of the conferences a schedule was devised whereby blueprints go through the regular release as before but, instead of going direct to the planning department first, one print goes direct to the tool department. This change probably will speed up work and give advance information to the tool department concerning planning.

CONCLUSIONS

1. Shop work constitutes the larger part of aircraft manufacture. It is most important, therefore, that the engineers, draftsmen and tool designers cooperate to the nth degree so as to insure a smooth flow of production.

2. Aircraft factory manufacturing is so complicated that it requires numerous conferences among the foremen of all departments.

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Cooperation Between Departments (Cont'd)

FIFTH MEETING

(Report of this meeting omitted because it dealt with details of tooling peculiar to the airplane manufacturing plant.—Ed.)

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CHAPTER V

Quality

SIXTH MEETING

(While the following analysis of the Douglas quality problem is specific, the principles apply in most plants, and the reader need only substitute his own products and conditions in order to have a statement that applies in his own plant.—Ed.)

One of the most important factors to be considered in manufacturing airplanes is quality. It is especially difficult to maintain high standards of quality in aircraft factory work where many different kinds of mechanics are employed. In many instances the work done is similar to regular trade work; for example, a craftsman machinist may easily adjust himself to the work.

However, a great many jobs differ radically from any other kind of work. There seems to be no way to learn these jobs except by specific training given

*The suggestions were made by the group, and the changes were announced by the engineering department, at the next meeting; they are inserted here for the sake of clarity in presentation.—Ed.

by the company on the job. This means that all aircraft factory work must be well coordinated to maintain a high quality.

Aviation concerns must keep in mind that, not only must the planes satisfy their customers as to appearance and cost, but they must be built to conform to high standards of workmanship to protect the lives of people.

An airplane concern builds up a reputation based on the quality of its product. Therefore, it must be very careful to see that no defective products are placed on the market. This means a continual check-up by all supervisors, employees, and employers who build the planes.

Naturally employers in the airplane business are intensely interested in the quality of planes produced. The employees should also be interested. It is safe to assume that the work of the employees determines the success or failure of the manufacturer.

Every employee must understand that whatever job he has to do must be done so well that no one can criticize his work. Employees often feel that the main thing to do is to get a job out. But aircraft factory work must be done right. Poor workmanship may result in an immense cost (in case of failure or non-acceptance) and reflect upon the reputation of the concern. It behooves every employee in aircraft factory work to make every effort to do his job 100 per cent right.

This means that employees must be just as interested in the success of the organization as are the employers. Without a good reputation for quality, every employee in the concern is going to suffer just as much as the employer.

Many manufacturing concerns can throw out a completed job without taking a very serious loss, but in airplane construction it is impossible to cast planes aside, because a single plane represents a tremendous amount of money. The aircraft factory work is an excellent example of the work on small operations by many mechanics resulting in a modern airplane.

Every mechanic must understand that, even though he has a small part to do in the construction of an airplane, his small part is most important and must be done well.

There can be no weak parts in an airplane. Each mechanic in aircraft factory work must be given to understand that his part is a most important one; that it is the sum total of all work that results in the completion of an airplane; that each plane represents not only a big investment in money but also the finest type of construction for the protection of human life.

WHY AIRPLANES ARE EXPENSIVE

1. Production of a given type of plane usually is on a small-quantity basis.
2. Airplanes require high-grade materials.
3. Aircraft factory work requires fine workmanship.
4. High standards in aircraft construction cause a large percentage of rejected parts.
5. Aircraft construction calls for complicated design due to the need for saving weight.
6. There is a continual change of detail design.
7. A considerable amount of money is needed to develop experimental planes.
8. The time limit on building planes raises the cost.
9. Aircraft factory work involves much hand work.
10. All airplane work requires repeated inspection.
11. Aircraft factory work needs more experienced help.
12. Airplane specifications are specific and rigid.
13. There is a need for most accurate tooling in jigs for airplane construction.
14. There is need for great accuracy in parts in aircraft construction.
15. Aircraft work requires an elaborate protective coating on all materials.
16. Expense is incurred in aircraft work due to lack of standardization of requirements and design.
17. Aircraft construction is affected by fluctuation in volume because all work is done on contract.

The preceding list gives a fairly clear picture of some of the reasons for the high cost of aircraft construction. It also brings out quite clearly the need for cooperation in all departments in order to reduce to a minimum the causes affecting the cost of construction. Each one of the reasons might also serve as a topic for a conference. For example, one reason given was: "Aircraft factory work needs more experienced help." This statement may raise the question as to where and how the experienced help can best be obtained.

HOW QUALITY CAN BE IMPROVED

Three general groups are involved in maintaining a high standard of quality. They are the mechanic on the job, the supervisor, and the manager.

HOW THE MECHANIC ON THE JOB CAN IMPROVE QUALITY

1. Report any troubles to his foreman immediately.
2. Carry out orders.
3. Follow details to the letter.
4. Take pride in his workmanship.
5. Look ahead on his job to prevent errors.
6. Learn how the other fellow's job fits in with his.
7. Cooperate with his fellow men.
8. Work in strict accordance to plans but detect errors and notify his foreman.
9. Realize the importance of his job.
10. If a mistake is made, notify foreman immediately, but do not cover up.
11. Suggest new methods of doing things.
12. Use the right tools in the right places.
13. Be extremely careful of all operations.
14. Do every operation the best way possible.
15. Maintain high standards of workmanship.
16. Cooperate with other workers and foremen.
17. Take up training in some evening extension classes.
18. Read up in aviation journals.

HOW FOREMEN CAN IMPROVE QUALITY

1. Make continual inspection.
2. Help select competent, trained men.
3. Get cooperation of men.
4. Be on lookout for bad practices.
5. Be on lookout for poor workmanship.
6. Keep check on methods and tools used by men.
7. Plan work so sufficient time can be allowed.
8. Keep the man on the job he is best fitted for.
9. Change drawings to expedite production.
10. Get good will of men.
11. Check when material moves between departments.
12. Plan to use good factory methods.
13. Insist on high standards.
14. Insist on men following all orders.
15. See that men receive proper instruction.
16. Give all men a square deal.
17. Insist that each man do his work well.
18. Inspect materials and equipment continually.
19. Work together with other departments.

20. Do a good job of supervision with men, materials, and equipment.
21. Help to make working conditions pleasant.
22. Recommend to the management men who should be promoted for doing high quality work.

HOW MANAGEMENT CAN IMPROVE QUALITY

1. Provide good working conditions.
2. Hire competent help.
3. Make promotions from inside company whenever possible.
4. Make more contacts with departments affected before setting delivery date.
5. Accept recommendations of foremen for promotion and increase of pay for men in their departments.
6. Plan a certain rate for each class of work.
7. Provide tools and equipment needed in each department.
8. Provide adequate means for storage of finished parts and sub-assemblies, etc.
9. Provide capable engineers.
10. Incorporate good manufacturing methods.
11. Improve and excel in designs in aircraft.
12. Provide good working conditions—adequate janitor service, ventilation, lockers for clothes, good floors, recreation facilities, cafeteria.
13. See that proper materials and supplies are delivered to the departments.
14. Create interest in quality.

As stated before, aircraft factory work consists of many different departments. Each department has to do with many different operations. It is necessary that each mechanic be interested in the quality of work which he turns out. Every worker must understand that his job depends on how well he does the work, and he should be impressed with the fact that the efficiency and safety of a completed plane depend on the accuracy with which every man does his bit.

Aircraft factory construction has one advantage over other manufacturing plants. In this industry all workers can see the finished product. This gives each man a better appreciation of how his part helped with the construction and appearance of a plane. It also brings out quite clearly that every man's work must represent a high standard.

CONCLUSIONS

1. The management, foremen and men are vitally concerned with quality.

2. Every operator must be impressed with the need for good workmanship.

3. There is a need for trained men in aircraft factory work. It might be well for the industry itself to develop some kind of training program.

CHAPTER VI

Waste in Industry

SEVENTH MEETING

One of the most serious problems confronting all industries is the question of waste. Anything that is wasted in the way of time, material, or supplies is gone forever and is a dead loss.

Industry is making a serious attempt to prevent waste. We are now working under hours and conditions different from those of several years ago. This is the age of economy, and all industrial concerns must pay particular attention to any "leaks" which add expense and for which no value is received.

It is the job of every foreman to check on the work of his men and on the amount of materials and supplies used. Too often we are not interested in saving on minor items. However, when we count up all minor items of waste over a period of years, we find that they add considerably to the cost of production.

EXAMPLES OF WASTE

After thoroughly discussing the need for foremen to pay particular attention to the elimination of waste in their departments, we made a list of the possibilities of waste in the aircraft construction industry.

The group listed the following typical causes of wastes which might occur in any aircraft company:

1. Too much time wasted waiting for inspection of airplane parts.
2. Lost motion in handling airplane parts.
3. Lost time in handing out tools for mechanics.
4. "Robbing" the job.
5. Lack of equipment.
6. Splitting orders.
7. Poorly designed tools, jigs, and fixtures.
8. Too long to straighten out engineering errors.
9. Errors in designing.
10. Slow telephone service.
11. Waste of material due to handling.
12. Time and material waste from incomplete templets.
13. Lack of enough blueprints.
14. Lack of proper details.

ANALYZING THE FOREGOING WASTES

It is demonstrated that a foreman in aircraft construction must continually check on waste—not only as to time, but as to supplies. The foregoing list could be grouped under the following headings:

Man-power waste
Material and equipment waste
Organization waste.

We next listed some of the examples of waste which might occur in any aircraft factory, with solutions for elimination.

MAN-POWER WASTE IN AIRCRAFT FACTORY

Types of Waste	*Suggestions for Elimination*
Department might have to wait too long for inspection of plane parts.	More cooperation from aircraft inspectors. More aircraft inspectors if necessary.
There may be lost motion in handling parts of planes.	Group operations in aircraft factory work so as to save time.
There may be lost time in handing out tools.	More tool rooms.
It is often necessary to "rob" a job.	Replace parts immediately after taking.
The telephone service may be slow.	Install automatic telephone in each department.
Old methods of production may be in use.	Supervisor must see that the best and newest methods for aircraft factory work are used in each department.

Too much time may be wasted in training green help.	Hire skilled help. Put someone on a training job. Put a few green learners with trained men. Set up a training program in a trade school.
There may be waste due to splitting orders.	Better planning on the part of the supervisor and men.
There may be a lack of proper details.	More accurate details of airplane parts in all cases involved.
There may be a lack of sufficient blueprints.	More blueprints regarding plane parts in certain cases for departments involved.
Tools, jigs, and fixtures may not be properly designed.	Better designed tooling. Consult men who are to use fixtures to see if they have any ideas or suggestions.
An industry may lack equipment.	Provide more equipment.
It may take too long to straighten out errors by engineers.	More time should be given to designing and checking.

SUPPLY AND EQUIPMENT WASTE IN AIRCRAFT FACTORY WORK

There may be waste due to handling equipment and materials.	Better equipment, better storage, and more careful handling by mechanics.
Possibility of templets being incorrect.	Check jobs more thoroughly before putting out templet. Closer inspection of templets.
There may be errors in designing.	Take more time for designing and checking. More capable aviation engineering personnel.
There may be waste due to material not being properly laid out.	Cut to templet instead of stock size.
Possibility of loss of equipment from departments.	Suggest supervisors make more careful inspection and check-up.
Possibility of careless handling of equipment such as electric drills and electric lights.	Suggest stop crowding tools in production work. Give special care regarding dropping tools.
Possibility of poor workmanship and construction.	Supervisor should see that the part is done right before inspection. Supervisor should see all work before it gets too far.

ORGANIZATION WASTE IN AIRCRAFT FACTORY WORK

There may be a lack of information on drawings.	It was suggested that drawings should include all necessary explanation and information so that the drawings are very clear to the mechanic.
There may be a lack of departmental correlation.	Aircraft factory construction has so many different departments that it is necessary for each department to cooperate and to know what the other department is doing.
Possibility of too elaborate a system for handling problems.	It is always advisable to use the easiest, the quickest, and the best methods for getting things done.

INFORMATION REGARDING AIRCRAFT FACTORY WORK

Aircraft construction is made up of "parts." It is up to the supervisor to conserve and to see that these parts are all constructed right. The success or failure of parts to stand inspection has much to do with the success or failure of the completed airplane. In the aircraft factory work all supervisors are concerned with a great variety of materials, such as new types of metals, many different kinds of fabrics, different types of wood, various kinds of composition, various forms of rubber, different forms of leather, and almost everything from cast iron to steel. While the quantity on hand may not always be so large, it is most important to have some of all of this material on hand and that the material be of good quality.

In an industry of this type we have approximately twenty-four trades represented. This calls for constant cooperation and correlation of work by the supervisors of all departments.

CONCLUSIONS

1. All foreman are vitally concerned with waste.

2. An efficient department is one that has very little waste.

3. The job of a foreman is to be continually on the lookout to eliminate all types of waste.

CHAPTER VII

Interest in the Job

EIGHTH MEETING

(We have omitted three lists that were compiled at this meeting: Kinds of Tradesmen and Professional Men Employed in the Construction of Aircraft; Some of the Material Used in Aircraft Construction; and Some Purchased Parts Necessary in Aircraft Construction.—Ed.)

A foreman is held responsible for getting things done; however, things cannot be done on time and in an efficient manner unless the foreman pays attention to the interest of the men in their work. Interest in the job is a very important factor and has much to do with the kind of work put out.

We next discussed some of the causes for loss of interest in the job. The group gave some of the following cases:

Case 1: A man quit because he was not satisfied with his pay. Cause for loss of interest: ***Not satisfied with wage.***

Case 2: A man worked in the paint department. The fumes from the paint affected his lungs. Cause for loss of interest: *Health.*

Case 3: A man worked hard to get a job done right. His foreman came along and criticized him severely. Cause for loss of interest: *Lack of encouragement in his work.*

Case 4: A good mechanic suddenly seemed to do a lot of worrying. It affected the amount and kind of work he did. Upon investigation it was found he was worried about home problems. Cause for loss of interest: *Trouble at home.*

Case 5: A foreman had a relative working in his de-

partment. This man often received preference on jobs. Other employees in the department lost interest. Cause for loss of interest: *Partiality.*

Case 6: A foreman saw someone doing something wrong. Instead of teaching him how to do it correctly, he "bawled" him out in front of others. Cause for loss of interest: *Bawling out in front of others.*

Case 7: A skilled mechanic had been working for a certain company for years. The company sold out to another company. The machinist liked his work but wanted to make a change as he did not like the policies of the new company. Cause for loss of interest: *Dissatisfaction with company policies.*

Members of the group gave various other causes for dissatisfaction. One had to do with the shop being too noisy; in another case the man was dissatisfied because he was given a minor job; in another case the man claimed the light affected his eyes; in another case a man refused to work on Saturday because of his religious belief.

The only reason for listing these cases is to bring out quite clearly that each foreman must investigate the causes for lack of interest on the part of the men in his department. Often we are inclined to say the man is not capable, or that he is lazy. Usually we do not attempt to make a scientific investigation as to the causes for his lack of interest. It seems that there are two factors involved in a happy relationship between the employers and the employees. They are *Interest* and *Satisfaction.* How can these two factors be defined?

Interest—That which causes a man to *want to work* on the job.

Satisfaction—That which causes a man to *want to continue to work* on the job.

We next listed some of the factors which affect the man on the job.

WHAT DOES A GOOD MECHANIC WANT?

Good wages.
A job that he is satisfied with.
Good working conditions.
A job that has some responsibility.
A job that has some difficult problems to work out.
A company that he can be proud of.
Pleasant relationship with his fellow workers.
An opportunity for promotion.
A chance to take part in social activities.
A reward for work well done.
A job where his work is appreciated.
To be recognized as an important unit in the company.
Some plan for security.
A good boss.

A FOREMAN'S RESPONSIBILITY

This conference brought out quite clearly that a foreman must have a knowledge of how interest factors affect men and how a satisfied workman affects quality and quantity of production. This means that each foreman must study his men so that he can scientifically analyze the "man problems" which are continually occurring.

The foreman faces the following added responsibilities: (a) He must see that his men are interested in their jobs. If they are not interested, he must find out the reason why and try to arouse their interest; (b) He must do everything he can to keep his men satisfied in their jobs. In case there is any dissatisfaction in his department, the men should feel free to come to the foreman and discuss the entire matter without reservation.

Each and every industrial organization may well work out some kind of scheme so that the efficient man with ability, initiative, and capacity will have opportunity for promotion.

CONCLUSIONS

1. Foremen must know what men want that will make them satisfied with their jobs.

2. A foreman must see that his men are interested in their jobs.

3. A foreman must do everything he can to keep his men satisfied with their jobs.

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Training for the Aircraft Industry

NINTH MEETING

(The report of this meeting omitted because of its specific appeal to a single industry.—Ed.)

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CHAPTER VIII

Solving Problems by Conference

TENTH MEETING

In another meeting we discussed various methods of getting things done. One of these methods was by *conference.* Through conference procedure a group of foremen can get the men in their department together and discuss departmental problems. Acting as conference leader, the foreman can help his group to arrive at definite conclusions regarding the solving of these problems. This method calls for group thought and action, which means that all of the men in the department must get together, work together, think together, learn together.

CONFERENCE WITH DEPARTMENT HEADS

We understand, of course, that it is important that the management call together all foremen for conferences. This is especially true in aircraft construction factory work because of so many different departments. One of the men gave the following example: *Lining up for beginning to release for production of a new model.* Whenever it is necessary to produce a new model some of the following people must go into conference:

Project engineer.
Supervisor of planning department.
Production manager.
Production schedule engineer.
Assistant sales manager.
Materials control supervisor.

The purpose of a conference with this group of department heads is to determine how to do some or all of the following:

Work out details.
Plan on how the work can be routed.
Determine how drawings will be made.
Make allotments to shops.
Publish index of releases bulletin.
Publish master section list bulletin.

It would be almost impossible to do efficient, satisfactory work unless these department heads first got together to discuss the entire plan for procedure. This is an excellent example of conferences with department heads.

CONFERENCES WITH MEN IN THE DEPARTMENT

An actual case was given: In a certain organization the men complained because the department head did not discuss company matters with the men in his department. For example, the officials of the company took up with the department heads the matter of safety-first. A thorough discussion was given to this matter—the causes of accidents, the costs of accidents, and certain suggestions for cutting down the number of accidents. However, in this case, the department head neglected to call together the men in his department afterward to discuss this matter with them. Consequently, each man received a little information here and there, and now and then, but no one in the department had a complete picture of what the company officials were trying to do regarding safety-first.

To remedy this, it was suggested that each department head call together the men in his department and, by means of the conference method, open up the entire matter of safety-first. This meant that the man on the job was to have an opportunity to make suggestions, to criticize, and to make recommendations regarding a matter of vital importance to the company. Most men are keenly interested in working out practical solutions to problems. They also feel that their job is important because they are helping to solve some of the company problems.

VALUE OF CONFERENCES

When men in a department are called together to discuss certain problems which affect their work, they have a better appreciation of the importance of their place in the industrial concern. It is often much better for an entire group to attack a problem and arrive at some definite conclusion than it is for the foreman or supervisor to attempt to solve the problem alone. Men want to contribute. They want to feel that they are an important part of the industrial organization. Then, too, men actually on the job may have a number of suggestions which would be very much worth while. The importance of every department head getting his group together to discuss departmental problems cannot be over-emphasized. It would seem that the conference method is an excellent way to create intelligent employer-employee relationship.

EMPLOYER-EMPLOYEE RELATIONSHIP

One of the chief problems confronting all industrial organizations at the present time is the problem of employer-employee relationship. Working men today are especially concerned with securing favorable working conditions.

In many cases it is possible to avoid misunderstandings through conferences. Supervisors or foremen can play a very important role in handling problems of this type. We know that the supervisor or foreman represents the company to the men, but we also must remember that he represents the *men to the company.*

We recognize, of course, that all supervisors or foremen are paid for getting things done. No matter what the job is, it must be done right, and on time. However, we also realize that it takes men to do these jobs. So, back of the ability to turn out material there will always remain the *ability to handle men.*

If the supervisor or foreman is going to represent the company to the men, he must be close to his men. Men in the department judge the company more or less by the actions of the supervisor or foreman. If a supervisor or foreman is frank, has meetings with his men, and seriously and fearlessly discusses problems that come up in his department, he will probably receive the good will of his men.

FUTURE TRAINING FOR THE AIRCRAFT INDUSTRY

The group again discussed the possibilities for developing training opportunities for the aircraft industry in some educational institution. The group stated that in many instances men apply for jobs, stating that they are trained mechanics. After a few days' try-out the plant finds that the men are not qualified. It would seem that industry cannot afford to take the time and spend the money for trying out applicants. Industry's job is to produce. Industry should be able to go to some institution and receive trained help. A trade school can be of special help by, first, selecting the right kind of young men for training; and, second, by training these selected men according to trade requirements and standards.

All trade training programs should have a trade committee of representative leaders in that field.

TRAINING MOST IMPORTANT

In one of our other conferences we stated that there was a marked tendency toward equalization of hours and costs of material and equipment. We also stated that it was impossible to standardize knowledge, skill, and morale without some kind of training. It would seem, then, that all industrial organizations should be intensely interested in some kind of organized training program.

CONCLUSIONS

1. The conference method is an excellent method for establishing better employer-employee relationships.

2. Conferences should be conducted with foremen. Foremen should also conduct conferences with men in their departments.

ARMCO POLICIES IN BUSINESS

Supervisory Discussion Program*, The American Rolling Mill Company, 1934-35

INTRODUCTION (Nov. 5, 10)

a. Purpose of the Course
b. History of Armco Policies
c. Revised Armco Policies
d. Colorful Illustrations of First Days of the Policies
e. Armco Policies Good Business

FAITH IN MEN (Nov. 18, 24)

a. Interpretation: "From its very inception, Armco has pinned its faith to men; has believed thoroughly that success in modern enterprise can come only through cooperative effort."
b. Mutual Interest: "Without a true mutual interest there can be no serious application, no real loyalty, no cordial cooperation, and little chance for concerted, effective effort."
c. "Loyal Organization": "To make every reasonable effort to develop and maintain an efficient, loyal, aggressive organization."
d. Sound and Efficient Personnel: "Through the development of much of mutual confidence based on understanding and fair dealing within the organization, to build a working personnel that will strengthen from year to year, that will insure progress, and make for permanence in operation and employment."
e. Employee Representation Plan
f. Application of Armco Policies Good Business

SQUARE DEAL (Dec. 2, 8)

a. Interpretation: "To insist on a square deal always to everyone."
b. Understanding: "To secure such clear understanding of individual and group attitudes, of the problems involved, and of our joint relation to our company, to ourselves, and to society at large, as will result in the creation of 'A Spirit of Responsibility' where there may be 'Irresponsibility'; of 'Cooperation' where there may be 'Antagonism'; and of 'Good Will' where there may be 'Suspicion and Distrust."
c. It is only through keeping the entire Armco group informed on all subjects affecting the company and the individual that we can have understanding.
d. Armco Policies Good Business.

INCENTIVES (Dec. 16, 22)

a. Interpretation: "To provide every possible and practical sound incentive to best effort."
b. Armco Spirit: "To develop 'Armco Spirit' in the highest degree within the organization."
c. Best Equipment: "To provide the best equipment obtainable, suitable to the particular needs of our business."
d. Pride in Accomplishment: "Never to be satisfied with anything less than the best results possible of attainment."
e. Compensation: "To provide not only fair, but the best compensation to employees for service rendered that it is possible to pay under the changing conditions which exist from time to time."
f. Application of Armco Policies Good Business.

OPPORTUNITY FOR ADVANCEMENT (Dec. 30, Jan. 5)

a. Selection and Placement of Men.
b. Promotion on Merit.
c. Check- or Follow-Up of New Men.
d. Application of Armco Policies Good Business.

LIVING AND WORKING CONDITIONS (Jan. 13, 19)

a. Relation between Company and Employees:
(1) "To create and maintain good and safe working conditions." To provide good living conditions by encouraging workmen at each plant to take part in community affairs, and thus improve morale.
b. Relation between Company and the Community: "To realize that Industrial Stability is influenced very greatly by civic conditions"—"That conditions which make for human unrest and unhappiness must to a large extent be remedied by each community and by each industry for itself." Therefore—"to do everything possible and practicable in the creating and maintaining of a working partnership between industry and the community."
c. Relation between Company and the Nation: "To realize that National Industrial Stability, or Instability, simply reflects the sum of the average conditions that exist in the individual communities." Therefore—"to develop and encourage real Americanism and a live spirit of patriotism, within and without our organization."
d. Armco Policies Good Business.

QUALITY AND SERVICE (Jan. 27, Feb. 2)

a. Interpretation: "To adopt 'Quality and Service' as a slogan, representing quality not only in product, but in organization, plant, property, and equipment; and service to Customers, Stockholders, City, State, and Nation": to make our products and services indispensable to our customers.
b. Right Way vs. Expedient Way: "In all decisions affecting the conduct of the business, always to consider what is right and best for the business as a whole, and not what may be expedient in dealing with a single situation."
c. Fair Treatment of Customers: "In the treatment of Customers to be fair and always fully considerate of their needs. To make promises as to delivery, quality, and service so conservative that on the average they can be exceeded."
d. Cooperative Management: "To maintain an efficiently cooperative management."
e. Application of Armco Policies Good Business.

ETHICS IN BUSINESS (Feb. 10, 16)

a. Interpretation: "To do business guided and governed by the highest standards of conduct and ethics known to the business world."
b. Application of Armco Policies Is Good Business.

APPLICATION OF ARMCO POLICIES (Feb. 24, March 2)

a. "To be consistent in the application of Armco Policies to each and every situation." "To accord to each individual or group associated with the company in any capacity such a degree of consideration as his, her or their individuality or particular situation justifies or requires."
b. To be persistent in the explanation and application of Armco Policies. By one means or another, emphasis must be maintained on every important policy, in order that its effect may be made permanent.
c. Application of Armco Policies Good Business.

SUMMARY (March 10, 16)

*Based on the statement of Armco Policies originally approved by the Board of Directors, Dec. 12, 1919, rewritten Dec. 1, 1934, subsequently published and distributed.

GENERAL MOTORS TRAINING PROGRAM

Outline of Printed Material

SECTION A—Management and the Executive Job
1. The place of management in modern industry
2. Principles of efficient organization
3. Analysis of the executive job

SECTION B—Planning
1. Planning in an industrial enterprise
2. Planning in the department
3. The development of planning ability

SECTION C—Quality Control and Waste Elimination
1. The control of quality
2. The control of scrap
3. The control of waste
4. What is inspection?
5. The inspection and salvage departments

SECTION D—Equipment
1. The fundamentals of equipment control
2. Tool control
3. The tool and maintenance departments

SECTION E—Building and Maintaining the Organization
1. Building the department organization
2. The personnel department
3. The control of labor turnover
4. Proper supervision

SECTION F—Principles of Handling Men
1. Personnel relations in industry—historical evolution
2. Dealing with men—individual differences
3. Dealing with men—human motives and desires
4. Dealing with men—influence of the group
5. Dealing with men—problems in human behavior
6. Dealing with men—intelligence and training
7. Handling men—getting along with people
8. Handling men—difficulties with subordinates
9. Handling men—giving and receiving orders
10. Incentives—employee morale and morale control
11. Securing cooperation
12. Judging and rating men

SECTION G—Employee Relations
1. The background of employee representation
2. Types and objectives of employee representation
3. Results obtained with employee representation plans
4. Plans of employee representation in General Motors
5. The executive's relationship in employee representation plans

SECTION H—Incentives
1. Wages
2. The relation of the executive to wage questions

SECTION I—Policies
1. The executive and company policies

SECTION J—Safety
1. The safety program
2. The problem of workmen's compensation

SECTION K—Job Study
1. The methods of work department
2. Principles of job study
3. Time and motion study

SECTION L—Training
1. The problem of training in industry
2. Training and the department
3. Methods of applying training

SECTION M—Housekeeping
1. Industrial housekeeping

SECTION N—Fundamentals of Economics
1. Development of economic organization
2. Modern economic organization
3. Elements of economics

SECTION O—Financial Organization and Control of Business
1. Invested capital
2. Borrowed capital
3. Financial analysis

SECTION P—Budgets
1. Business conditions
2. Forecasting
3. Departmental budgets

SECTION Q—Departmental Cost Control Methods
1. Departmental cost reports
2. Direct materials cost
3. Direct labor cost
4. Departmental expenses
5. General overhead

SECTION R—Personal Characteristics
1. Personal analysis

SECTION S—General
1. The requirements of modern industrial leadership

The Demand of the Future

W. S. KNUDSEN
Executive Vice-President
General Motors Corporation

TIMES change; laws get passed. We sometimes wonder what it is all about, because we have been doing work a certain way successfully and for a long time. But the fact that we have been doing things a certain way for a long time doesn't mean anything. We can do them a different way, as long as we never lose sight of the prime objectives:

Quality first; cost second;clean places to work; no accidents; good wages; no discrimination on account of age; and finally, the most important part of all, picking young, bright executives to carry the load when the rest of us have got to lay down our tools.

FUNDAMENTALS OF FOREMANSHIP

Prepared by Rutgers University, University Extension Division, for an Eastern manufacturing concern

SESSION 1—Responsibilities

Instructions as to methods and requirements of the course.

Brief lecture on the need for systematic training.

Discussion of the leader's responsibilities. Group asked to name them. This list developed on the blackboard somewhat as follows:

The Leader's Major Responsibilities or Objectives:

1. *Costs*—to keep costs as low as is consistent with quality.
2. *Quality*—no job should require doing over on account of poor workmanship, the wrong material or because done out of its proper sequence.
3. *Quantity*—to get work done on time without resorting to emergency measures as an oversized working force, excessive overtime, or causing other departments inconvenience.

These objectives are interdependent, and the wise leader keeps them in balance. In doing so he finds that there are a number of secondary responsibilities to which he must give proper attention. These responsibilities, or jobs, involve planning of equipment, material, and personnel; training men; receiving, interpreting, and giving orders; inspecting work; coordinating the work within his department; cooperating with other departments; cleanliness, orderliness, and maintenance of good working conditions, safety, morale, etc.

Each member of the group is asked to estimate on paper the percentage of his time spent on each responsibility.

SESSION 2—Responsibilities

A general discussion of the scope and meaning of responsibilities. Many of the group will be made aware of responsibilities which they had never applied to themselves seriously. The knowledge that they are *managers,* not merely overseers or "bosses," will serve to secure added interest in the analysis of their problems during the remainder of the course.

SESSION 3—Leadership

Lecture on the new conditions in industry that call for a higher type of leadership for the man in the ranks. Discussion of some of the leader's jobs such as developing intelligence in his men, securing their respect, their interest, and their loyalty. Some qualifications of the effective leader. Discussion of self-rating methods for the leader. Each member required to rate himself on a form provided.

SESSION 4—Lighting

Lecture and discussion on the effects of improper or insufficient light. Development of a set of standards to guide the foreman in maintaining adequate lighting conditions.

SESSION 5—Cleanliness, Orderliness, and Other Working Conditions

Development, through discussion, of a list of standards necessary to prevent waste of time, material, and supplies, and to produce safety of operation. Development of methods of maintaining standards. Brief lecture on importance of sanitary washrooms, lockers, accessibility of drinking water, etc.

SESSION 6—Analysis of Costs

Lecture on the primary factors in the industrial enterprise—land and buildings, machinery and equipment, men, material, management, the investor. The items of cost involved in each of these factors are developed on the blackboard, presenting an impressive picture of the complexity of modern industry.

The responsibility for each item of direct and overhead cost is then discussed, so that each member of the group may see his own numerous cost responsibilities in isolation. Items of joint responsibility, such as maintenance of machinery, housekeeping, etc., are also discussed.

The written assignment requires that each member of the group list all his exclusive and joint responsibilities separately, explaining the most important of them.

SESSION 7—Waste in the Handling of Materials

Materials handling as an important factor of cost in (1) labor, power, and machinery necessary to move it; (2) excessive handling due to poor routing or piling; (3) delays and inconvenience caused by improper expedition and placing of material; (4) reduction of fatigue and accidents through better methods of handling materials.

A clear explanation of these and similar problems leads to an interesting general discussion on problems actually met in the work.

At the conclusion some of the most important standards for handling materials within the department are given. A written description of some materials handling problem is required of each member, to be turned in at the following meeting.

SESSION 8—Waste of Machinery and Equipment

Lecture and discussion of wastes caused by (1) improper operation, (2) improper care, (3) delayed or makeshift repairs.

Early in this discussion each member of the group has his attention drawn to the machinery and equipment in his own department.

The session concludes with a discussion of general rules or standards that may be used to insure economy in the use of machinery and equipment.

SESSION 9—Waste of Material and Supplies

Development through discussion of waste of such supplies as lubricants, repair supplies and materials, lights, small tools, compressed air, personnel equipment, etc.

Enumeration of various ways in which supplies and materials are wasted. How such wastes may be reduced. If convenient, some information from company records as to the total annual cost of various items would be advisable. Also any available records of spoiled or wasted material would be of value in impressing the group with the possibilities of waste prevention.

SESSION 10—Waste Due to Labor Turnover

Lecture on the cost and extent of labor turnover. Causes of labor turnover. Reduction of labor turnover among new workers by proper induction into the life of the plant and by efficient methods of training.

General discussion and development of specific methods of dealing with the new worker so as to secure his intelligent cooperation.

SESSION 11—The How and Why of Job Study

Lecture on the importance of scientific study of jobs. Description of several important purposes for which jobs are studied. General discussion, on the basis of wastes brought out previously, of the immediate needs for job study by members of the group. Methods of job study

available to the foreman or leader. Written assignment requiring analysis of a job for the purpose of teaching it to the new workers.

SESSION 12—Training the New Worker—Organizing the Material

A demonstration of job analysis for the purpose of training, with the cooperation of one or more members of the group. General discussion.

SESSION 13—Training the New Worker—Putting It Over

Lecture on the various methods of teaching available for use in the shop.

Development through discussion of methods to be used in teaching the job previously discussed. Written assignment—completion of training outline for jobs analyzed after Session 11.

SESSION 14—Safety and Production

Lecture on the prevalence and cost of accidents in recent years.

Discussion of the causes of accidents. This discussion is directed to demonstrate that safety and efficient production are closely related.

Development of methods of safety education for the plant.

SESSION 15—Cooperation

Lecture on necessity of cooperating with superiors, subordinates, and other departments.

Discussion of specific methods of cooperation.

SESSION 16—Review

Brief lecture summarizing the course. Discussion of the high spots by members of the group. Presentation of certificates.

FACTORY SUPERVISORS COURSE

Used by International Business Machines Corporation

THIS curriculum outlines briefly the subject matter that has been laid out as part of a two-year program of weekly meetings. One or more meetings are devoted to each subject, depending upon interest and timeliness. Printed lesson material is supplied on each subject as the supervisors progress through the course. This material is frequently supplemented by case studies that have been furnished to the instructor by the supervisors themselves.

SECTION I

The Factory and the Field

Purpose: To present to the factory supervisors a picture of the applications of our products in the field and the responsibility of the supervisors in the performance of our products *after* they have been shipped.

1. Development of International Business Machines Corp.
2. The Purpose of and Field for Tabulating Machines.
3. The Purpose of and Field for International Time Recorders.
4. Demonstration of Tabulating Machines.
5. The Manufacture and Use of Tabulating Cards.

   Shown in two moving picture films. The first picture is a reel entitled "The Manufacture of the Card," and the second, "The Story of the Census," illustrating the use of the card.
6. The Part Tabulating Machines Play in Business.

   A brief descriptive booklet illustrated with actual reports for such applications as payroll accounting, material accounting, and sales analysis.
7. Demonstration of International Time Recording Products.
8. Field and Purpose of International Scales.

   This lesson deals primarily with the discussions of the advantages obtained by the accurate recording of materials in all departments of the factory, beginning with the receiving room and ending with the final shipment.
9. Cooperation between Factory and Field Organizations.

   A discussion of the problems arising in the field.

SECTION II

Duties of a Supervisor

Purpose: To impress upon the supervisors that they deal with six highly important elements: Men, Machines, Management, Minutes, Money, and Materials.

1. Supervisor's Job.
2. Supervisor's Responsibility for Self-Improvement.
3. Supervisor's Responsibility for Building the Organization.
4. Supervisor's Responsibility for Direction and Organization of Manufacturing.
5. Supervisor's Responsibility for Training Personnel.
6. Supervisor's Responsibility for Handling Men and Maintenance of Plant Morale.
7. Supervisor's Responsibility for Safety.

SECTION III

Prevention of Waste

Purpose: To consider the origin and causes of waste and to indicate to the supervisors the ways and means by which they may be controlled or prevented.

1. Waste of Labor.
   (a) Due to idleness, lack of training, poor planning, tardiness.
   (b) Due to poor workmanship.
   (c) Through turnover.
2. Waste of Materials.
   (a) Direct material.
   (b) Indirect material.
3. Waste of Machinery and Equipment through
   (a) Improper operation.
   (b) Inadequate maintenance and makeshift repairs.
4. Waste and Costs of Accidents and Illness.
5. Waste of Light, Heat, and Power.
   (a) Electric current, steam.
   (b) Compressed air, water.
   (c) Coal and heat.
6. Waste of Space.
   (a) Cleanliness and order.
   (b) Proper storage.
7. Prevention of Waste through Study of Cost Sheets.

145 TYPICAL TOPICS FOR FOREMAN TRAINING MEETINGS

Selected (the first 124) by the Department of Manufacture, U. S. Chamber of Commerce, and published as part of a survey made in cooperation with 90 separate companies that have had experience with foreman training. These 124 topics have been supplemented by others that are suggested by present-day economic problems

1. Analyzing Yourself
2. Development of Personality
3. Effective Leadership
4. Importance of Observation
5. Investigation before Conclusions
6. Decision vs. Snap Judgment
7. Tact and Diplomacy
8. Resourcefulness
9. Originality
10. Inventive Ability
11. Imagination
12. Enthusiasm—Is It Contagious?
13. Adaptability to Conditions
14. Does Ambition Produce Initiative?
15. Openmindedness
16. Willingness to Accept Suggestions
17. Systematic or Haphazard
18. Physical Fitness
19. Mental Alertness
20. Example of Character
21. Forming Habits
22. Utilizing Time
23. The Foreman's Responsibility
24. Analysis of Job
25. Knowing Men
26. Developing Men
27. Developing Interest
28. Training Workers
29. Starting the New Man
30. Getting Teamwork
31. Labor Turnover
32. Safety and Accident Prevention
33. Maintaining Discipline
34. Attendance
35. Orders — Directions — Suggestions
36. Securing and Using Suggestions
37. Coaching an Understudy
38. Service—What Is It?
39. The Working Force
40. The System and the Worker
41. Labor and Production
42. Loyalty to Management and to Men
43. Honesty and Square Dealing
44. The Foreman and Labor
45. The Foreman and Management
46. The Foreman and Industrial Service
47. The Foreman and the Social Order
48. The Foreman and the Law
49. The Foreman and Inspection
50. The Foreman and Stockkeeping
51. The Foreman and the Inventory
52. The Foreman and Costs
53. The Foreman and Waste
54. The Foreman and Production
55. The Foreman as an Instructor
56. The Foreman as a Supervisor
57. The Foreman as a Leader
58. Knowledge of Position and Job
59. Basic Factors in Production
60. Methods of Getting Production
61. Flow of Work
62. Departmental Relationships
63. Loss through Spoiled Work
64. Keeping Equipment in Order
65. Records and Reports
66. Improving Workmanship
67. Receiving and Storing Material
68. Issuing Material
69. Movement of Material
70. Care of Material
71. Fabricating Material
72. Our Labor Policy
73. Employment—Right Man on Right Job
74. Wage Policy
75. Wages and Incentives
76. Non-Wage Incentives
77. Time Study
78. Setting of Rates
79. Rating Employees
80. Promotion
81. Discharge or Transfer—Which?
82. First Aid
83. An Attractive Place to Work
84. Man and Materials
85. Man and Machine
86. Buying—Storing—Producing
87. Management's Responsibilities
88. The Art of Management
89. Organization of the Company
90. Products of the Company
91. Making the Organization Effective
92. General Factory Equipment
93. Working Machinery to Capacity
94. Providing Machinery with Power
95. What Is Purpose of Planning?
96. Manufacturing Costs
97. Selling Costs
98. Industry Yesterday — Today — Tomorrow
99. Industrial World, a System
100. Trends in Organization and Specialization
101. Labor-Saving Machinery
102. How Is Business Financed?
103. Sources of Material
104. What Production Is and Who Produces
105. Factors in Production
106. Production and the H.C.L.
107. What Is Included in Overhead
108. Problems of Distribution
109. Law of Demand and Supply
110. Business Enterprise and Profit
111. Economics of Our Business
112. Competition and Monopoly
113. Price, the Basis of Industry
114. How Our Product Is Marketed
115. Credit and Banking
116. Thrift — Investment — Personal Finance
117. The Source of all Capital—Savings
118. Why Banks are Indispensable
119. Stocks—Bonds—Brokers
120. Speculation vs. Investment
121. The Ups and Downs of Business
122. Governmental Regulations and Requirements
123. Labor Movements
124. The Foreman's Place in Industry
125. Wages and Profits
126. The Share of Labor
127. How Business Begins
128. The Funds of a Corporation
129. Off the Gold Standard
130. Stabilizing the Dollar
131. War Debts
132. The Tariff
133. Poverty and Prosperity
134. Unemployment Compensation
135. Old Age Pensions
136. Health Insurance
137. Share the Work
138. Standards of Living
139. Mechanization
140. Obsolescence
141. Technological Changes
142. Alternatives to Capitalism
143. NRA
144. Collective Bargaining
145. Can We Have Overproduction?

SELECTED READING

THE ART OF LEADERSHIP
Ordway Tead, McGraw-Hill Book Company, Inc.

FOREMAN TRAINING THAT WORKS
R. G. Adair, *Factory and Industrial Management*, May—October, 1930.

PERSONAL LEADERSHIP IN INDUSTRY
David R. Craig and W. W. Charters, McGraw-Hill Book Company, Inc.

PRACTICAL FOREMANSHIP
Glenn L. Gardiner, McGraw-Hill Book Company, Inc.

THE TECHNIQUE OF EXECUTIVE CONTROL
Erwin H. Schell, McGraw-Hill Book Company, Inc.

PSYCHOLOGY FOR EXECUTIVES
Elliott Dunlap Smith, Harper & Brothers.

BUILDING MAINTENANCE

Economical maintenance of industrial buildings and structures is carried on best when a definite schedule of inspection and repair is followed by informed personnel.

Some details should be inspected weekly, some monthly, some every six months, and so on. A proper schedule will specify these times. They will be determined from self experience and from the reported experiences of others.

After a long period of neglect, such as we have just passed through, building maintenance must be started from scratch. Everything must be inspected. Extra effort, repair, and expense must be contributed to pay for past negligence.

This 16-page treatise on Building Maintenance, and the Check Chart that accompanies it, are designed to enable the men charged with plant operation to begin all over—inspect thoroughly, reach conclusions as to what to do in building maintenance, how to do it, and what to do it with; then to go on from there with a regular preventive program for economical plant operation.

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Chapter One

WHAT TO LOOK FOR

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STRUCTURES begin to disintegrate as soon as they are exposed to the action of the elements or are placed in operation. They must be maintained or eventually they will become useless. A system of periodic examination of all parts of the structure is the best insurance for the investment in structures. These inspections should be made at least annually, but I have found that it is frequently better to make them semi-annually. Complete inspection should be made now of any building that has been neglected for one year or longer.

Organize for the Job

It has been my experience that management may have more assurance that all parts of the structure have been thoroughly inspected when a definite report covering the major parts of the building is made. A form that I have used with good results is given in Table I on the following page.

Inspection of a structure, when detailed report forms such as that given in Table I are used, may safely be entrusted to a capable mechanic. Blank forms are provided for field notations on the condition found and, when major repairs are reported as necessary, either the owner or chief engineer may reinspect the conditions before authorization for repairs is approved in order to insure the most economical repairs with adequate safety.

The work of making the repairs may be executed by a maintenance organization composed of carpenters, plumbers, steam fitters, painters, etc., or may be let out by contract to firms specializing in work of the type required. In smaller organizations the minor items usually are taken care of by general utility men and the more specialized work is let to competent contractors after competitive bidding.

It is always desirable, when dealing with contracting firms, to have their proposals definitely describe the work included in the quotation to prevent later misunderstanding.

Authorization of Repairs

The inspection report, when properly made, calls the actual conditions to the attention of those responsible for the upkeep of the structure. Estimates of cost for correcting the disintegration shown should accompany the report so that the management will be in possession of all facts necessary to make a decision as to which work shall be authorized. Consideration may then be given to the cost of correcting both major and minor defects. Major defects will be those which, if allowed to continue uncorrected, will cause structural weakness or affect the usefulness of the structure. Minor ones will show conditions which, if corrected in time, will prevent progressive disintegration and larger expenditures at a later date. It is the timely authorization of minor repairs that lessens the total long-time maintenance cost.

Cost Records

A simple record of maintenance expenditures is useful in showing which methods and materials are best adapted to particular uses, and this record when carried over a period of a few years can serve as a guide for the better selection of materials and design for future construction. Table II outlines an "Analysis of Maintenance Expenditures" that I have always found very effective.

Most of the expense incident to restoration and repair work either

Table I—Structural Condition Report

Foundation—Report interior and exterior condition of foundation walls and piers. Indicate whether there is evidence of settling, moisture, leakage, cracking.

Exterior Walls—Report individually condition of all exterior walls, including coping and parapet walls. Note pointing where needed, as well as moisture penetration into parapet or other walls, if any. Report condition of paint if exterior walls are of wood.

Exterior Window Frames, Sash, Doors—Condition of glass, putty, frames, sash, sash weights, locks.

Roof Deck, Roofing, Flashing, Pent Houses — Include everything above the roof, such as pent houses, tanks, and tank supports. Special care should be exercised to ascertain condition of flashing.

Columns, Girders, Beams, Joists—Report for each floor separately.

Floor Wearing Surfaces—Report for each floor separately.

Note: Floors subject to heavy moving loads on steel wheels, or acids, alkalies, or greases should be constructed of material selected to resist these conditions, or floor repairs will be excessive.

Note: Floors may be resurfaced with asphalt or rubber tile, magnesite, wood, emulsified asphalt, or asphalt plank, as well as other materials. The use of a surfacing material frequently makes old worn-out floors usable at a moderate cost.

Electrical Wiring — Report on adequacy of feeders, insulation resistance, condition of conduits and supports.

Sprinkler System, Fire Pump, Water Tower—Report condition of each item.

Water Piping and Sanitary Lines.

Note: Plumbing lines are expensive to maintain and alter. Only the best of materials should be used, to keep future maintenance to a minimum. The water in many localities is of such nature that corrosion frequently deteriorates steel and some iron pipe very quickly. To overcome this, copper and wrought iron are used extensively.

Heating Equipment—Include condition of steel and brick stacks, piping, boilers, pumps, other boiler room heating equipment.

Exterior Platforms, Walks, Driveways, Fences, Grounds—Report need for repairs and replacements.

Elevators—Special attention is to be given to condition of cables, guides, limit switches, and motive equipment.

Miscellaneous—Report on condition of interior walls and incidentals not covered elsewhere. State color of paint used and year of last painting when making recommendations for repainting or cleaning.

Note: The use of a cheap paint for walls and ceilings is seldom economical. The cost of labor used in applying the paint forms the larger part of the total painting expense. Consequently even though one paint, which may be 25 per cent to 50 per cent higher in first cost, is used it withstands cleaning for several years longer than a cheaper paint and is more economical in the long run.

Note: Movable-type partitions are especially desirable where they may be satisfactorily used. They are made in either wood and glass or metal and glass and may be rearranged for future needs with little expense.

Note: Small out-buildings may be grouped under a single notation.

Building number, inspector's name, and date of inspection must be included in the report

can be avoided entirely or controlled to a minimum if building owners and management executives will give proper consideration to certain fundamentals of sound building construction and maintenance routine.

I have found that the following recommendations are helpful in keeping maintenance costs at a minimum:

1. Plan the new structure or such alterations to the existing one as are found necessary, and use materials that are suitable for the operation to which the structure is to be put and the locality in which it is to be erected. Place the work under competent architectural or engineering guidance.

2. Choose a competent contractor and pay him a fair price to build the structure, or engage capable mechanics to make the alterations under suitable direction.

3. Institute a periodic inspection of the entire structure after its erection, and have submitted to the management comprehensive reports showing the condition of the separate parts of it.

4. Promptly authorize such maintenance work as the report shows is necessary.

5. Maintain a simple record of the work performed and the cost incurred.

It has not been the intention in this chapter to present specific recommendations for the treatment of all conditions encountered in structural maintenance or alterations. They are so numerous that individual chapters on the various subjects are advisable. I have attempted to focus the attention of those charged with the upkeep of structures upon the major factors involved in the control of huge annual expenditures that have in the past, and will soon again reflect themselves in the costs of the products made in the buildings.

Table II—Analysis of Maintenance Expenditures

Fences, Walks, Driveways, Platforms, Grounds—Include cost of repairs and replacements.

Exterior Walls, Including Foundations—Include the cost of pointing, caulking, painting, waterproofing, and other repairs of all exterior walls, doors, sash, etc.

Roofs and Flashing—Include cost of repairs and replacements.

Floors—Include cost of cleaning materials, equipment, and labor used in cleaning floors. Report maintenance costs of various types of floors separately; that is, wood, concrete, tile, mastic, etc. All labor and material incurred through repairs to floors are to be included under the separate groups.

Interior Structural Supports — Include repairs to columns, girders, roof beams, etc.

Interior Walls—Include cost of interior painting, cleaning of walls, ceilings, and structural supports, as well as washing of windows.

Electrical Distribution System—Report under this heading the cost of (a) Bulbs, fuses, and other supplies used in maintaining the system; (b) all labor expended on the system, including the cleaning of the fixtures.

Heating System—Report the cost of (a) Supplies used to maintain heating system; (b) all labor used in connection with repairs to the heating system.

Water Piping and Sanitary Lines—Include the cost of maintaining the sprinkler system, including pumping equipment, tank, towers, water and drainage lines. Report cost of (a) All labor used in maintaining the system, including labor of painting; (b) all supplies used in maintaining the system, including paint.

Elevators — Include cost of repairs and parts replacements.

Miscellaneous—Cost of any maintenance not otherwise reported. (Itemize on a separate sheet, indicating nature.)

ROOFS

FACTORY ROOFS should be thoroughly inspected at least once a year. The following suggestions as to the points that should receive particular attention apply especially to built-up or composition roofs, since this type is more widely used for factory buildings.

Parapet walls are frequently the source of leaks apparently due to defects in the roof. Many brick parapet walls are porous, especially if laid with soft brick, with lean mortar, or with joints imperfectly filled. The joint between metal cap flashings and brick parapets is often a source of leaks. Keep caulked with an elastic cement.

Metal flashings may in time become corroded and require replacement. Leaks may be caused by expansion and contraction of metal flashings or other parts; either condition may cause trouble at joints in flashings. In some cases it is necessary to install additional expansion joints in metal flashings.

Composition flashings may also leak, especially at their junction with parapet walls.

With roofing mopped to metal-base flashings, having strips of roofing felt mopped over the flashing, an imperfect bond or a partial separation of roofing and flashing may cause leaks. This joint should be examined carefully.

Junction of roofing to flanges or flashing around conductor heads is a troublesome point, and should always be checked when leaks show up at or near roof outlets.

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Bare spots or bubbles in built-up roofs with slag or gravel surfaces will lead to trouble. They should be smoothed out and patched after cleaning the slag down to solid felt.

A small puncture may be troublesome because water may follow the top of the roof deck for some distance before appearing inside. In such cases, it may be easier to scrape back the surfacing and apply a new mopping over a fairly large area, instead of making a number of patches.

On new buildings having high-grade, built-up roofs always look first for trouble from parapet walls, expansion, flashings, and junction of roofing with other materials.

Check Roof Covering

With buildings having old roofs that have not given trouble for many years, any leaks that occur are likely to be due to the roof covering itself.

In general, when built-up roofs more than 15 years old develop leaks and require frequent patching they should be replaced. However, many tar and gravel roofs have given satisfactory service for 30 years or more.

Composition or built-up roofs, Table I, have been developed to a high state of reliability. It is possible to purchase such roofs covered by a bond insuring the owner against maintenance expense for a period of 20 years. Although the majority of factory roofs today are of this type, there are a number of other types that have special advantages for certain types and locations of buildings. Some constructions that combine deck and waterproof covering are shown in Table II.

Is Everything in A1 Shape?

When a new roof covering is to be installed, put all construction affecting the roof into first-class condition. Wood decks should be gone over carefully and defective or questionable material replaced. Imperfect drainage should be corrected, low places eliminated. Parapet walls and flashings should be examined. In many instances new flashings will be necessary; see that they are made of the proper materials and correctly installed. Make provision for expansion and contraction of flashings.

Table I—Features of Composition or Built-Up Roofs*

1. Width of felts used	30 to 36 inches
2. Materials of felt	Rag stock, or asbestos fiber
3. Impregnation of felts	Coal tar pitch, asphalt
4. Mopping between and over felts	Coal tar pitch, asphalt
5. Weight of felts	14 to 15 lb. per 100 sq.ft. is most common, but they are made in other weights up to 40 lb. per 100 sq.ft.
6. Number of plies	Cheapest roofs are two and three ply. Five plies usually used for 20-year roofs
7. Finished surface	Gravel imbedded in pitch or asphalt Slag imbedded in pitch or asphalt Special, mineral-surfaced cap sheet, and other special cap sheets Smooth coating of asphalt
8. Total weight per square foot	Smooth-surfaced roofing: 1½ to 2½ lb.; slag-surfaced, 5 to 6 lb.; travel-surfaced 6 to 7 lb.
9. Range of costs	7 to 12 cents per sq.ft. in place, without flashings

**This type of roof is suitable for flat or sloping roof decks, subject to the following limitations: Gravel surfacing should not be used on slopes exceeding 2 inches in 12. Coal tar pitch should not be used on steep slopes. Asphalt with slag surfacing can be used on slopes up to 6 inches in 12.*

Prepared or Roll Roofing**

1. Usual width of sheets	36 inches
2. Common weight of sheets	35 to 75 lb. per 100 sq.ft.
3. Costs in place per square foot	2¼ to 3¾ cents

***Applied in one thickness, usually with 2-in. lap cemented. Should be used only on slopes of 4 inches in 12 or steeper. Suitable for sheds, temporary buildings, and like structures.*

With new construction, or when an old roof is to be replaced, the matter of roof insulation should be carefully considered. When high humidity is maintained inside a building the roof should be insulated to prevent condensation and dripping, which may damage equipment or products, as well as collection of moisture on the inner surfaces of flashing or roofing materials. Condensation here will frequently lead to rotting of wooden parts.

How Insulation Pays

Roof insulation will help to: (1) Reduce heat losses, with resultant reduction in fuel consumption and the amount of radiating surface required; (2) make it easier to maintain fairly even temperatures inside the building; (3) prevent condensation, with its resultant deterioration of the building and its contents.

What Insulating Materials?

Insulating materials for roofs are divided into four general classifications—the rigid-board type; the semi-rigid board; the flexible felt-like sheet type; and the cast-in-place or cellular type.

Included in the rigid-board types are the various fibrous insulating boards. They are made by compressing wood, sugar cane, or other vegetable fibers, either with or without a binder, into large sheets, ordinarily about ½ inch in thickness.

Cork represents the semi-rigid type of insulating material.

Flexible types of insulating materials for roofing application are made from waste fibrous materials formed into a felt-like mass ranging from ½ to 1 inch in thickness.

All insulation must be protected against wetting before, during, and after application. Materials in common use average by volume 75 per cent air and 25 per cent solids, and since water conducts heat fourteen times better than dry air the uselessness of wet insulating material can be appreciated. For each 1 per cent gain in weight from wetting, the thermal conductivity of the material increases about 4 per cent.

How Thick?

Determination of the thickness of insulation to use depends on a number of factors that can not be discussed here. In general, however, from 1 to 2 inches of insulation usually strikes the proper balance between the added cost and the saving in fuel possible.

As mentioned above, all forms of roof insulation lose their effectiveness and tend to disintegrate when saturated with water. The permanence and effectiveness of the insulation, therefore, depends to a great extent on the character of the waterproof covering.

Although not always recommended by the manufacturers of insulating materials, the safest procedure when using roof insulation is to apply a waterproof membrane under the insulation before it is laid. This membrane usually consists of two layers of 14-lb. felt with all laps and joints mopped, and a thorough mopping given between the two layers.

A waterproof membrane of this kind prevents moist air from inside the building from reaching the upper surface of the insulating material, where it would be condensed and cause saturation of the insulating material.

Right Roof for Right Service

Satisfactory service from roofs can be assured only when the proper type is selected to meet the conditions. For permanent buildings of substantial construction there is no real economy in using cheap roof coverings. Vital points to be considered are:

1. Slope of roof deck and material of construction.
2. Spacing, strength, and condition of steel members, where roof deck and waterproofing are combined in one material.
3. Climatic conditions and geographical location of building.
4. Presence of gases and fumes detrimental to certain types of roof construction.

Table II—Roofing Materials That Combine Deck Construction and Waterproof Covering*

Material	*Usual Size of Sheets*	*Weight per Sq.Ft. of Roof, Lb.*	*Usual Spacing of Supports (Purlings)*	*Minimum Roof Slope, Inches*	*Approx. Cost, Cents per Sq.Ft., in Place*	*Remarks*
1. Corrugated iron, black or galvanized	Widths 27½ in. and up. Lengths to 12 ft.	1 to 2.25	5 to 7 ft.	4 in 12	11 to 21	20 or 22 gage recommended. Cost of copper-bearing steel and special irons is slightly higher than shown.
2. Corrugated, asbestos-protected metal	33 in. wide. Lengths up to 12 ft.	1.75 to 2.50	4 ft. 9 in. to 8 ft.	2 in 12	21 to 26	24, 22, and 20 gage. Lap joints laid in elastic cement. Obtainable coated with copper or aluminum foil, at added cost of 4c per sq.ft.
3. Corrugated sheets, portland cement and asbestos fiber.	Widths 27 and 42 in. Lengths up to 11 ft.	4.75 to 5.50	4 ft. 6 in.	2 in 12	18 to 25	$\frac{7}{16}$ in. thick at top and bottom of corrugations, $\frac{5}{16}$ in. on curves. Lap joints laid in elastic cement.
4. Interlocking cement tile	24x52in.	14 to 16	4 ft.	4 in 12	30 to 33	Tiles with glass inserts 19x31 in., $2.50 per tile extra.
5. Cast-iron plates	24x52 in. $\frac{3}{16}$ in. thick.	11 to 11.5	4 ft.	4 in 12	42 to 45	Laid with separate cover plates over side joints.

**To be used on sloping roofs only. Suitable for foundries and similar buildings where rapid heat loss through roof is not serious. Should not be used over rooms having high humidity, on account of condensation.*

WALLS (Waterproofing)

BUILDINGS that are new usually require little attention to the exterior surfaces for a period of time whose length will vary with the kind of structure, quality of workmanship, climatic and atmospheric conditions, and so on. However, after 4 or 5 years of exposure to the weather, weak spots and defects of one kind or another begin to appear. These defects must be given prompt and proper attention in order to prevent the serious damage that inevitably follows neglect.

When, or if, leaks are discovered in the exterior surfaces of a building they may be taken as a definite sign that serious trouble threatens and the entire building should be given a thorough examination by experienced men. The best time to make this examination is in the spring. Of course, whatever repairs are needed should be made at once.

Exterior Wall Inspection

It is advisable to make a close inspection of a building at least every two years by swinging a scaffold or boatswain's chair over the walls at the most exposed corners or areas to determine the kind and extent of repairs, major or minor, needed to keep the exterior wall surfaces in good condition.

Incidentally, it has often been found that the north and east walls are the ones that cause the greatest amount of trouble and, therefore, need the most attention, whereas the south and west walls do not require so much.

Before discussing the procedure to be followed in making a systematic inspection of building exteriors mention should be made of the fact that there are two general types of cracks that appear in all buildings. One is the settlement crack, and the other is the shrinkage crack. Each requires a different kind of treatment.

Settlement cracks are caused by settling of the building, by vibration, or by expansion and contraction. Usually there is a movement of the structure with this type of crack, and precautions have to be taken in order to prevent continued trouble.

The recommended method of treating such cracks is to cut them out to a depth of $\frac{3}{4}$ to 1 inch, where possible, clean, and prime. Then an elastic caulking material of a color that matches as closely as possible the surrounding areas should be forced into this crack to the full depth and properly finished off. This caulking material will remain elastic for years and will prevent further trouble, if properly applied.

The shrinkage crack is the other type. It appears in many buildings

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and there are numerous causes for it. The method of treatment involves cutting out the mortar joint sufficiently to permit careful packing of a properly prepared cement mortar. This mortar mixture should be composed of 1 part cement, from $2\frac{1}{2}$ to 3 parts of sand, by volume, and approximately 20 per cent of lime. The joints should be well cleaned and wet down with water before pointing. After the mortar has been thoroughly packed into the joint it should be properly tooled and again wet down before it takes its initial set, in order to prevent too rapid drying. Allow two or three days to elapse before applying waterproofing material.

Defective mortar joints should be treated in about the same way as shrinkage cracks.

Among the points that must receive careful attention during the inspection of a building are the terra cotta trim, cornices, or ornaments. Where cracks develop in such places and are neglected a piece is likely to break off and fall to the ground, perhaps causing serious injury to some employee.

Projecting Areas Go First

The parapet walls of a building, both inside and outside, are usually the source of a good deal of trouble and require more attention than any other areas. Window sills and other projecting courses of masonry also require close attention; it is usually found that heads and sills of windows and cornices or projecting areas show deterioration more quickly than other parts.

Parapet walls should be inspected carefully on the inner surface from coping down to the roof line. If flashings have given away they should be repaired. If there are expansion joints between flashing and roof they should be given attention. These joints, if found to be cracked, or defective, should be cut out to their full depth, properly cleaned and primed, and recaulked with either an elastic caulking material or with a liquid asphalt cement, heated and poured in.

The back or inside of the parapet walls should have all mortar joints cut out and properly repointed wherever settlement or expansion cracks appear. The walls can then be coated with either a transparent waterproofing material, a regular black roof coating, or better still, a layer or two of asphalt-impregnated fabric. The fabric should be stuck down with a full coat of plastic asphalt between each layer, with a final heavy coat of the same material. If this method of protection is used, the fabric should be applied vertically and lapped approximately 4 inches at all joints.

Look for Cracks in Coping Stones

Coping stones and the exterior of parapets are the next item for inspection. Any cracks found should be carefully cut out to a sufficient depth to allow for careful repointing. If it is likely that continued movement of the structure is to be expected the cracks should be pointed up in the same manner as described above for settlement cracks. If, however, no movement is likely, the directions covering the treatment of shrinkage cracks should be followed.

Since coping stones are exposed on three sides they will remain in much better condition when treated in about the same way as settlement cracks. They are always subject to a certain amount of expansion and contraction.

It is important that the bed joints, both inside and outside, of the coping stone also be caulked.

Defects most commonly found in concrete buildings are spalling of the concrete, corrosion of reinforcing bars at or near the surface, or other projecting areas. With brick or stone buildings defects show up more often at the mortar joints, or as structural cracks which may have

been caused by vibration, settling, or expansion and contraction.

Repairs needed in concrete buildings should be carefully made, since any new concrete that is put in will not last long unless a good bond is secured and properly anchored into the main wall with sufficient reinforcing to hold the new material securely. With concrete panels the trouble usually encountered is in the bonding joint, also in the joint between the column and panel. To correct this condition the cracks should be treated in the manner outlined for settlement cracks.

For Exterior Concrete

Waterproofing treatment for exterior concrete surfaces consists in the application of a penetrating waterproofing material. A transparent material may be used, but if it is desired to decorate the surface or cover up any stains a colored cement coating will be needed. At least two coats of either type of material should be applied by brush or spray, allowing 24 hours to elapse between the application of each coat. These materials are prepared and sold by manufacturers of paint and waterproofing compounds.

With terra cotta buildings, or those that have terra cotta ledges, ornaments or trim, a good deal of trouble is encountered from spalling or cracking of this material. The trouble is caused primarily by the mortar joints opening up or becoming defective and permitting the entrance of moisture which in cold weather freezes, expands, and causes the destruction of the terra cotta.

To correct this condition it will be necessary to repoint the mortar joints with cement mortar, in the same way as shrinkage cracks. Wherever terra cotta is subjected to unusual exposure, as in the case of ledges, cornices, or ornaments, the repointing should be done with an elastic caulking material, similar to that mentioned for settlement cracks. However, if the terra cotta has been damaged by spalling it can usually be repaired by filling in the spalled areas with cement, which should be securely anchored, and a waterproofing material applied over it.

Brick or stone buildings usually need only careful repointing of cracked, open, or defective mortar joints, which should be treated in about the same manner as shrinkage cracks. However, if the brick is of a porous or absorptive nature a waterproofing material should be applied over it. The material used should be of such nature that it will not discolor the surface any more than is necessary or unavoidable. Some of these waterproofing materials are composed of a large proportion of mineral spirits and very light oils. Others have mineral spirits as a base, with a larger volume of oils or waxes. Care must be taken in choosing the proper material for the surface that is to be treated. The proper material to be used and the method of applying it should be determined before any extensive application is made.

The caulking around window and door frames is very important, since it protects and preserves the frame, keeps out cold air and drafts, and prevents the entrance of moisture. In treating window frames, caulking can be done by removing hanging stiles, packing with an oakum yarn, and putting in the caulking material around the frames under gun pressure; then the staff beads should be securely nailed back. Or it can be done by caulking around the exterior perimeter of the frame, using an oakum yarn as a packing where the opening is larger than ¼ inch, and forcing the caulking material around the frame under gun pressure.

In concrete and other factory buildings the window frames, which are usually steel, have a tendency to buckle, thereby preventing the sash ventilators from opening and shutting properly. This condition can be overcome by cutting away masonry at the heads and sills of the frames so as to relieve the pressure and thereby allow for expansion. Then the frame should be cleaned, scraped, wirebrushed, carefully primed, and caulking material forced in around the entire perimeter of the frame, under gun pressure.

Below Ground Level

What has been said thus far applies, of course, only to those portions of the building that are above the ground. Most industrial plant buildings have basements; hence, the lower part of the walls extends below the ground level. Unless precautions are taken moisture or rain water is likely to penetrate foundation walls and produce highly undesirable conditions.

Waterproofing of foundation walls presents problems that should properly be left to the expert for solution. Conditions vary much; so each case requires careful study to determine the best procedure. In general, however, two distinct conditions are encountered: (1) Presence of surface water only, with little or no hydrostatic pressure; (2) permanent presence of water in the soil, with definite hydrostatic pressure.

Drainage Always Important

Getting rid of surface water is usually a matter of proper drainage. Open drain pipes laid along the outside of the walls, at the bottom, and covered with loose rock and earth is often sufficient to carry away the water. Again, drain pipe and loose rock, covered with earth, may be laid in a trench a short distance away from the walls. The water should be led to a sewer or dry well.

When trouble is caused by ground water under pressure a different method of treatment is required. In one procedure an effort is made to transform the walls and floor into a water-tight inclosure that will withstand the pressure of the water. Another method involves relieving the water pressure by drain pipes that discharge into the sewer or into a sump below the floor level, which is emptied by a pump.

With both of these methods it is necessary to waterproof the walls and floor, since concrete is ordinarily not water-tight. When a building is being erected certain patented materials or preparations may be mixed with the concrete to make it more or less impervious to water.

After Building Is Built

Waterproofing the foundation walls after erection necessarily involves application of an impervious coating to either the outer or the inner surfaces of the walls. In so-called membrane waterproofing several layers of impregnated felt, jute or cotton are applied to the outer surface of the walls, below ground level, and covered with hot pitch or asphalt. Membrane waterproofing is also used under the floor. Drain pipes may or may not be used under the floor to relieve pressure.

When foundation walls are waterproofed from the inside a coating of integrally waterproofed rich cement and lime mortar is applied to the inner surface of the walls and on top of the floor. The coating is usually about ¾ inch thick on the walls and is put on in two layers. A somewhat heavier layer is applied to the floor, since it is subject to wear.

FLOORS

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DESIGN of floors for strength is the first consideration; it should equal or exceed that of the structural framing of the building. The second consideration is the use to which floors are to be put. Probably the most important factors to be considered are wearing quality, chemical resistivity, quietness, cleanliness, and appearance.

Wear on floors by hand or lift trucks is particularly severe in aisles and at machines, loading doorways, and elevator shaftways. It is here that wear first shows and, assuming the floor to be structurally strong, it is first evidenced by pitting or rutting of hard, brittle surfaces such as concrete, and by splintering and shredding when wood is used. Heavy loads on the usual small truck wheels cause grinding and crushing of the floor surface, which eventually breaks down. Hence the proper type of floor and surface must be used to insure maximum service before repairs begin.

Wear Faster, Do Less Damage

It is also well to consider the use of composition or rubber-tired wheels on trucks, which wear out faster than metal-tired wheels, but do less damage.

In recent years chemistry has revolutionized many processes and created new ones, so that in many plants acids and alkalis play an important part in building deterioration. The action of these solutions on certain types of floors can easily result in structural failure, as well as damage on floors below from leaks.

Guard Against Acids

In reinforced concrete floors acids may work into cracks and eat away reinforcing at vital points, unnoticed until failure results. In plating rooms, oil and sugar refineries, canning factories, and the like, where acid, oil, or brine come in contact with wood, metal, or masonry floors, maintenance costs have been high because proper materials were not used in or on floors. Surfaces, particularly masonry, should be treated either with special penetrating solutions that are resistant to the chemicals used, or they should be coated with asphalt or other resistant material, preferably 1 inch or more thick, and the area so treated curbed and drained.

Quietness is often desired and is best obtained by surface coatings that are either an integral part of the floor or a covering over one that is now noisy. A resilient material that is tough is usually required. In areas of hard usage it must also have high wearing qualities.

To Increase Floor Life

1. Minimize vibration. Keep the floor supported and fastened as solidly as possible. Movement causes internal, often excessive stresses that will damage it.

2. Build with foresight. Ascertain the points of heavy or maximum traffic and protect the surface with wearing plates or treads, as at elevator and loading doors, aisles, ramps. Shocks from impact or grinding action may soon penetrate the surface; then the damaged area spreads rapidly. Treat or coat the surface in areas where dust must be eliminated, or where chemicals may affect it.

3. Make repairs at once. Damaged areas spread rapidly. Either remove the cause of the damage and correct the error in construction, or repair the damaged area while it is small.

4. Don't guess at what to do or how to do it. Information can always be obtained from those who really know and may be well worth what it costs, if anything.

Where noise is caused by trucking, various types of wheels, other than steel, may be used on masonry, metal, or other hard-surfaced floors.

Cleanliness is always desirable, oftentimes imperative. Dusting of concrete floors can be partially eliminated by treatment before they are used, which also tends to lengthen their life. Floors that require washing must be water-tight and should be treated or coated. Before using chemicals for cleaning, see that the material used will not eat away the surface or stain the floor.

Repair Again or Renew?

Once repairs are necessary to a floor there is usually a constant fight to extend its life. Somewhere comes the time when the cost of repairs will balance the cost of a new floor; so the inspection, estimate, and decision will lead to savings or loss. The decision to put in new floors or repair the old usually rests with the management, which should be guided by the recommendations of the plant engineer. Cost, possible future use, probable length of time of present use, probable life of the building, and many other considerations must be balanced.

Check These Points

For this reason careful inspection is very important. Some of the points to be checked are:

1. Is the floor strong enough for the required loading? If not, what is needed?

2. If of wood, is it securely fastened to the beams. Is the framing securely fastened together, so as to minimize vibration?

3. Are there any cracks? Is the wood slivering or splitting? Are there ruts or holes in the surface? Where are the areas so affected? Why has it occurred? Can the cause be eliminated, or must repairs continue?

4. If the floor is supposed to be watertight does it leak through the surface, at the curbing, or at drains and connections?

5. Are there complaints about dust, noise, accidents, slipping, difficulty of moving trucks, penetration of cold, moisture, fumes? If so, ascertain the location and extent of

the affected areas. Then decide whether it is the fault of the floor or some condition that may be corrected readily.

Other points pertinent to special uses will come up in many instances.

If a floor is solid and structurally strong the service it will render depends on the quality of its surface and its suitability to the usage for which it was installed.

In brick and tile floors, rather rare in factory areas, hard burning and glazing give the protective surface. For concrete floors, special top finishes with hard aggregates and treated metal filings, metal strips in grating form, filled with concrete, anchored steel plates, and other construction help to protect the body.

Water-Tight and Acid-Proof

Asphalt or composition floors for water-tightness or acid resistivity can be placed over metal, wood, or masonry. Where hardness is needed they may be made of high melting point materials or have particles of some wear-resisting substance suspended in the matrix near the top. However, they must be tough and not crack, or leaks will result. Reinforcing can be placed in these materials, and is especially advisable over wooden floors or others prone to deflect under loading.

Wood floors present a softer wearing surface; even hard woods do not stand extreme wear for long. Special types of wood-block with the grain placed vertically give better wear than in a horizontal position, eliminating slivering and cracking. Treated blocks can also be obtained to prevent dry rot.

Armoring of old wood floors with steel plates is often satisfactory. The plates should be resquared and fastened with bolts having countersunk and slotted heads, with a washer and nut under the floor. Plates can be obtained with treads, but the surface of smooth plates will not be very slippery except where covered with water, oil, or very dry dust.

Smooth, Dry, Resilient

The finished floor should present a smooth surface to eliminate shock from impact and noise from trucking, and to increase the ease of moving trucks and the safety of employees.

From the standpoint of health a floor should be as dry, warm and resilient as operations will permit. On all floors the wet areas should be curbed and drained. On ground floors, dampness of masonry floors can be greatly reduced by a cinder fill of 6-inch minimum thickness. Porous concrete pipe or perforated tile drains placed under first-floor masonry floors tend to drain the ground and eliminate dampness.

If necessary, steam lines can be run at intervals under these floors for warmth and dryness, although the installation and operation are rather costly. A thin, portable wooden rack, linoleum, and the like may be placed at machines to lessen the effects of cold, dampness, and fatigue produced by damp or hard floors.

The table, which lists the most common types of floors used in industrial buildings, will be helpful when new floors are to be installed.

Types of Floors for Industrial Buildings

Description	Approx. Cost Per Sq.Ft., Dollars	Remarks
Stone concrete, 6-inch, reinforced (ave. 1:2:4) (on ground)	0.15 to	Good for storage areas and ordinary wear. Usually on first floors or for integral part of building itself.
¾- or 1-inch, grit-top, special finish on stone or cinder concrete base	0.25	Usually quick-finish process with machines. Very durable, hard, smooth. Treated metal filings add to surface life. Should be on solid base; structural cracks extend to surface. Good for many types of heavy manufacture and use.
Asphalt compositions (poured) about 1½ inch thick on concrete, brick, or solid wood base.	0.40 to 0.60	Usually for protection from acids, etc., and waterproofing of areas. Quiet and clean. Not good for very heavy trucking operations. Surface tough, but not so hard as concrete.
Protection of concrete by treatment or painting (about 3 coats)	0.02 to 0.06	Various media to suit specific needs. If structure of floor is cracked they will not make it waterproof. Keep down dust; many add to wearing quality of surface. Usually require 2 to 4 thin coats for good penetration. Paints require frequent renewal, but add to appearance. Concrete top can be mixed with ochres or other pigments for permanent color.
Tiles, linoleums	0.20 to 0.30	Usually for offices; are stuck to floor or set in mastic on concrete, brick, or wood. Appearance very good. Too frail for heavy manufacture. Usually quiet and clean.
Soft woods, 1¾ inches thick	0.15	Long leaf yellow pine, spruce, etc. Can be placed directly on floor beams. Not good wearing surface for trucking, but satisfactory for storage and like areas. Quiet, clean, healthful.
Hard woods, ⅞ inch thick	0.15	Oak or maple; good to surface over old wood floors in offices and light manufacturing areas. Set in mastic on concrete. Must be kept dry.
Hard woods, 1¾ inches thick	0.20	Oak and maple. Can be set directly on beams. Must be kept dry. Good for light and moderately heavy manufacture. Will not stand heavy trucking. Clean, dry, fairly quiet.
Wood block, 1- to 2-inch (grain vertical)	0.25 to 0.40	Best wearing of wooden floors under trucking. Should be kept dry even if treated. Quiet, clean, healthful. Can be set on concrete, brick, or wood base.
Steel plates, 3/16- to ¼-inch, on wood floors.	0.25 to 0.30	Can be installed while plant is operating. Very long life if properly fastened. Slippery under water, oil, dry dust.
Hard-burned brick, on edge	0.25 to 0.35	Very noisy with treads. Good in aisles and at points of heavy traffic. Long life. Requires structural base. Little dust from wear.

PAINTING

THERE is no one paint that will apply to all kinds of materials and satisfy all conditions. Consult your paint dealer and purchase suitable paint for each use. A paint designed for woodwork is not suitable for steel. Paints made for the interior of buildings are not of much value for exterior work. Surfaces that are kept at high temperatures require paint that will stand that temperature. Where steam or acid conditions exist, special paints are needed.

Remember the price of paint is its least important qualification. Use good paints. Cheap paints are not economical. It costs just as much, often more, to apply them. The life of a good paint is longer, and the saving in labor costs, due to fewer applications, exceeds the difference in cost.

Preparing the Surface

After the proper type and grade of paint has been selected, consider the surface. It must be clean and dry. All oils and greases must be removed. When paint is to be applied over old paint, the loose paint and blisters must be thoroughly scraped off. It is often necessary on steel surfaces to chip off all the old paint and on wood surfaces to burn off the paint down to the bare wood.

Do not paint new masonry and plastered or concrete surfaces, unless special paints are used, until they have thoroughly dried out, otherwise the moisture that comes out of the walls will loosen the paint.

Many a pot of good paint is wasted through poor application. Paint is composed mainly of an oil and some pigment. These ingredients separate and must therefore be frequently stirred while the paint is being applied. When purchasing paint in barrels, order barrels that have agitators. This will enable stirring as the paint is drained off in the painter's pot.

Life of paint depends to a great extent on thickness of film. A thick coat will not bond to the wall properly and will peel easily. If applied by brush, the paint should be spread evenly. This is also particularly necessary for spray painting. Labor costs can be reduced by the use of spray machines, but the application is more difficult and requires a skilled operator.

Three fundamental rules apply whether the work happens to be initial or maintenance painting. In painting new work never use less than two coats. For exterior work the use of three coats is advisable and economical. Most important of the three is the priming coat. It

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determines the life of the other coats and also of future coats. To have a good check on each coat applied, arrange for each coat to be a different color.

Another important item in reducing painting expense is to adopt a systematic painting procedure. It is not economical to delay the painting of steelwork until the old paint has deteriorated and the steel has rusted badly and scale has formed, because the cost of removing rust and scale to prepare the surface for new paint exceeds the cost of the paint and its application. If the painting is done before rust and scale are formed, the cost of the job will reduce by at least half.

Regular Inspection Needed

Structures should therefore be inspected at regular intervals and painting done before the ravages of the elements have proceeded too far. This inspection work is inexpensive. Do it at least once a year.

Paint exteriors only when the temperature is above 40 deg. F. and during the dryest season of the year. Inspect, therefore, at the end of the winter season.

The logical period for interior painting is during the winter season when the painting force cannot work outdoors. Interior work can be inspected during the early fall and a program arranged. Both exterior and interior inspections should be made by a man who can prepare specifications for the work.

Let us first consider exterior painting. Inspect now (April). The inspector should have a record of the time when each structure was last painted. A simple record can be kept by stenciling the date when painting was completed and the brand or mixture used.

Steel structures require more attention than others and should be thoroughly inspected, especially at joints in the framing and at pockets where dirt and water may lie. Sheet metal generally tends to corrode when sheets overlap. If numerous places are found where the paint has peeled and rusting has started, the entire structure should be given one or two coats, depending upon conditions.

On the other hand, if only a few rust spots are evident, the structure may be spot painted, provided the balance of the paint appears to have further life in it. This may be determined from its appearance. Or small pieces may be scaled off. The paint skin should be elastic and not dry; if dry and brittle, another coat will preserve the old paint, also the structure, and prevent corroding.

If Corroded

Instructions for repainting a steel stucture should state that all rust and scale be removed by wire-brushing and scraping. If the structure is badly corroded, it may be necessary to sandblast it. If the rust is not thoroughly removed, paint will be ineffective as the rust continues to increase even under a paint film.

After the rust has been removed, paint the bare metal with a good primer such as red lead and linseed oil, at least twenty pounds of lead to a gallon; a mixture of red lead, graphite, and linseed oil; red lead, iron oxide, and linseed oil; or a coal tar mixture. Finishing coats should be similarly compounded and tinted to color desired. Pigment content may be somewhat reduced in the finishing coats. Coal tar mixtures cannot be tinted, but can be covered with aluminum paint or special mixed colored paints.

Give new steel structures one good priming coat and at least one finish coat in addition to shop coat. Provide drain holes in all pockets. Turn steel members so as not to hold dirt. Expose steel tanks to the weather about six months to a year before any paint is applied. During this period the mill scale will disintegrate. Paint placed over mill scale

will come off with the scale. After the scale has disintegrated, the metal surface must be thoroughly wire-brushed and scraped or sandblasted. The surface is then ready for paint.

Before erecting new galvanized sheet metal, wash both sides with vinegar or copper sulphate solution, then apply a good steel priming coat of paint. Further painting can be done after erection. In this way all surfaces, where metal is lapped, receive a coat of paint. Considerable maintenance painting can be eliminated by using grades of sheet metal that inhibit rust. Special grades of steel, iron, and steel coated with lead instead of zinc are available.

Steel Sash, Fences

Inspect steel sash and fences and paint at regular intervals. Paint sash with ventilators opened. Place calking around the edges to keep moisture from attacking the portion of the sash that is set in the masonry. It is also well to apply at least two coats of waterproofing compound on window jambs and sills to keep moisture from seeping through the masonry and causing rust.

Before painting woodwork such as sash, doors and fences, the surface should be cleaned of all dirt, loose, blistering, or peeling paint, and sanded down to a smooth finish. If the old paint has dried out and wrinkled, it must be burned off. Wood should be well primed with white lead and linseed oil, or the white lead may be omitted. Wood treated with colorless solution can be purchased for new installations. This treatment retards deterioration of the wood and reduces the painting required.

Interior work involves the painting of wall and ceiling areas, steel sash, pipes, and floors. Metal surfaces should be given a good metal priming coat when first installed. This priming coat will generally protect the surface for its entire life. However, when pipes and other metal are located in shafts or tunnels where a hot damp condition exists, the surfaces should be given a priming coat and one or two additional coats of good metal paint at time of installation. These surfaces must be inspected every six months and repainted as needed.

For pipes carrying steam or hot liquids use paint that will not disintegrate under heat. Special paints are made for the purpose. It is good practice to devise a color code to indicate use made of pipe.

Paint and Light

Painting of interior walls and ceilings is needed to provide proper lighting conditions, not to mention neat, clean appearance. This is perhaps the most important phase of painting in the modern manufacturing plant. The type of paint mainly used is known as mill white. This paint is prepared with an oil vehicle or with a casein base. The oil-vehicle type produces a flat, gloss, or eggshell finish. The casein-base paint produces a flat finish and is odorless. This type of finish can be altered to eggshell if desired. Either can be applied to concrete, brick, steel, or wood surfaces. Before applying on steel, the surface must first receive a good priming coat.

Prior to applying the oil-vehicle mill white paint to concrete or masonry, the surface should be allowed to dry out thoroughly. Otherwise the alkali in the concrete and the oil in the paint will combine to form a soapy substance that causes peeling. On new masonry surfaces always apply a prime coat first, then a finish coat can be applied. Type of finish paint to use depends upon light conditions wanted. Eggshell seems to suit most conditions as it does not render too high a degree of light reflection. It is often necessary and desirable to tint white paint to reduce glare.

Because it forms a more porous film, the casein-base paint can be applied on damp surfaces. Two coats of this paint should be applied on new masonry surfaces, although it is possible on some surfaces to produce good results with one coat. Aluminum paint can be and is being used for interior painting with good results. Light reflection is good and not too severe.

The repainting of interior masonry surfaces offers some interesting problems. It is possible to wash surfaces where the oil mill white paint has been used. However, the cost of washing almost equals the cost of applying another coat and does not give the proper appearance or lighting effect.

When Paint Peels

Where the paint has peeled, it is due either to the alkali in concrete or to damp conditions. Before repainting, all loose paint must be thoroughly cleaned off and those areas repainted with a priming coat. Where a wet vapor condition exists over process kettles, special paint should be applied before repainting. Oil spots should be covered with a coat of shellac or aluminum paint or both if the condition is bad.

Where the surface has been previously coated with the old type of cold water paint, it should be cleaned off. If an oil-vehicle paint is to be used in repainting, add from one to two quarts of linseed oil to a gallon of prime coat before applying. If casein-base paint is used, spray entire surface with three parts of boiled linseed oil combined with one part of turpentine before applying paint; then only one coat is required to produce satisfactory results.

To sum up, painting is maintenance insurance, and like other forms of insurance the premium is small but the protection is great. It offers one of the best methods to combat corrosion and at the same time improve the value and appearance of your property.

The life of paint is limited at best. Repaint at regular intervals. Make inspections at least once a year. Repaint before excessive deterioration takes place. Give attention to the kind of paint used and the manner in which it is applied. Paint all new work thoroughly when installed. Painting properly done where and when necessary will prevent deterioration and hence reduce maintenance.

See reverse of Building Maintenance Check Chart for table of Painting Defects and Remedies.

Light Reflecting Value of Colored Paints

Color	*Per Cent of Light Reflected*
White, new	82-89
Cream	73-78
Ivory	62-80
Buff	61-75
Aluminum	65
Light green	49-66
Yellow	48-75
Gray	36-61
Light blue	34-61
Pink	30-46
Dark tan	17-63
Dark red	13-30
Dark green	11-25
Light wood varnish	42-49
Natural wood, stain	17-29

LOCKER AND WASH ROOMS

PROPER location of toilet and locker rooms depends upon whether the plant occupies a one-story or a multi-story building, size and shape of floors, and the operations carried out on these floors.

If the operations are carried out in one large open space, it is sometimes advisable to separate these accommodations so that there will be two or more toilet and locker rooms, reducing the distance which the workmen must travel. Frequently it is found desirable to provide locker and wash rooms adjacent to the point where the labor checks in and out, with toilet facilities convenient to the centers of activities of the various manufacturing operations.

The plant operating man can easily figure out for himself what proper location of toilet and locker rooms represents in dollars and cents, by determining the cost of the time required by the average employee to go to and return from these rooms. He may be surprised at what this means to him in money, especially when it is considered that the man will not dash madly out and back to his work but will take as much time as possible.

It is often possible to locate toilets or lockers on mezzanine floors. Or lockers are sometimes placed on a balcony within the toilet room. Such an arrangement conserves valuable floor space.

Where and What

The general arrangement of toilet and locker rooms depends on product, size and shape of building, and class of labor. It is well, however, to have separate rooms if at all possible, with separate entrances. A communicating door between toilet and locker rooms is desirable. With this arrangement, the locker room may be kept locked during working hours—a distinct advantage in some factories.

Where women are employed, a rest room should be provided even if it is not required by the State code. It may be a combined rest and locker room or a separate room with direct communication to locker and toilet rooms.

In many factories it is necessary to provide separate toilet and locker rooms for the common labor and for the skilled help, especially where the skilled help perform exacting work.

Toilet and locker rooms are constructed preferably with concrete floors and hollow tile walls. Provide a sufficient number of floor drains and slope the floors to these drains. Walls may be painted with enamel paint, finished with a waterproof plaster of Keene's or portland cement, or enamel tiled. In most plants,

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hollow tile suitably painted will give very satisfactory service.

A 6-in. coved cement base where floors join walls is desirable. With this type of construction, rooms may be flushed out.

About Ventilation

Adequate provision must be made for proper ventilation of toilet rooms. If located along outside walls, sufficient window area should be provided. When direct outside ventilation cannot be obtained, direct connection to the outside air by means of a duct system is satisfactory. If there is sufficient height to create a natural draft, no fan is required.

It is necessary, however, to bring air in. This is best accomplished by having the lower panel of the door constructed with louvres. Air drawn from the room, whether by natural or mechanical draft, should be discharged above the roof. In a multi-story factory, the toilet rooms on the various floors are often located one above the other to conserve stack and vent lines. In that case an adjacent shaft discharging to the roof offers the simplest type of ventilation that can be obtained.

When workmen are subjected to heat and perspire accordingly, locker rooms should be ventilated by mechanical means if located away from outside walls. This not only permits working clothes to dry when not in use, but also removes objectionable odors.

Fixtures for toilet rooms vary according to the labor employed, location of plant, the management's preferences, and size of pocket book. All fixtures should be of sturdy construction and designed to make replacements and repairs simple.

Trough-type water closets are seldom used in modern installations. Many states do not permit them. When they are permitted and when common labor is employed, they will serve the purpose.

Where enameled cast-iron water closets are permitted, use only for common labor. Vitreous china closets are permitted in all states. In certain industries, closets are provided with extra large traps to prevent clogging by foreign matter.

Whether fixtures are of the individual or continuous flush type depends on the industry, number of men employed, and cost of water. The individual type is provided with a separate tank or flush valve. The continuous type is used where the flushing is done at periodic intervals. The individual type requires more maintenance because of valve seat renewals, but uses less water. A well-designed flush valve in place of the tank is recommended for individual flush fixtures where the water pressure is sufficiently high.

Stall urinals are usually preferable to the wall-hanging or slab type. Again it depends on the class of industry. In a foundry, for example, I prefer the wall-hanging type. There is a likelihood of sand being brought in on the shoes of the workmen, and when the room is flushed out it is likely to lodge in the urinal pipe or traps. It is true that the dirt would be washed into the floor drains, but these drains are usually provided with a dirt pocket.

Water closets are preferably divided into cubicles by suitable partitions. Whether to divide urinals is a matter of choice.

Partitions

Many materials are available for toilet partitions. Wood is cheapest but most unsatisfactory. It absorbs moisture, is not easily kept in sanitary condition.

Most partitions in modern factory installations are metal with a baked enamel finish. They are comparatively inexpensive, serve the purpose well, although they must be periodically examined and painted.

One of the best materials is slate,

which is moisture-proof and odor-proof. It is higher in initial cost, but requires no maintenance beyond an occasional wiping with oil or kerosene.

Factory managers generally prefer to have no doors on toilet stalls because doors make inspection more difficult, also because they are conducive to greater waste of time. Sometimes one cubicle is provided with door and lock, for the use of foremen or department heads.

Wash Basins, Showers

There are many wash basins on the market, both of the individual and trough type. The individual type, although more expensive and costlier to maintain, is more desirable, especially where the hours are variable. The trough type with its constant flow of clean water or with sprays has been found satisfactory. Combination faucets for hot and cold water are recommended.

Shower baths are necessary in many industries. Slate stalls serve satisfactorily. Fixtures are usually arranged in gang form with all piping exposed, to make replacement and repair easy. Adjustable shower heads are usual, and proper precaution should be taken to spot them so that the room will not be flooded. Floors of shower stalls should be properly pitched to drains. This seems obvious, but it is surprising how little attention is often given to this detail.

Consider the use of an anti-slip compound or anti-slip tile on shower compartment floors; the prevention of accidents will often justify the added expenditure.

Every toilet room should have a slop sink if possible. These fixtures are not expensive and are a great convenience. For factory purposes, the tub is usually of galvanized cast iron. Enamel is likely to chip. A hose bib on the slop sink faucet is a convenient aid for attaching the hose used in flushing the room.

Soap and towels are usually furnished by the workman. Where the product requires extreme personal cleanliness, liquid soap and paper towels furnished by the management may be necessary.

Where the work is of such character that the workman requires a great quantity of soap in washing up, the clogging of drains and traps may sometimes be eliminated through the use of liquid soap.

There must be an adequate supply of hot water. Usually it is heated in a tank heater which may be located near the ceiling in the toilet room, if the room is far from a central supply. Covering heater and pipes is a good investment.

Water in trough basins is sometimes heated by means of steam blown directly into the water through a perforated pipe, but this is not recommended.

All plumbing piping should be of ample size. This is true not only of soil and vent pipes but also of water lines. Water piping that is too small will sooner or later clog up. Brass pipe and fittings, both for hot and cold water, are a good investment.

Design piping so that water systems may be completely drained. Do not run water pipes in front of windows or where cold air may blow directly on them.

Provide locker rooms with a sufficient number of clothes lockers, which may be of wood, although steel is in more general use. They may be arranged in tiers, one above the other, or full height in single rows. They should be provided with locks and hooks, and properly ventilated.

Clothes Lockers

In some plants where working clothes become impregnated with odors and perspiration, clothes racks are suspended from the ceiling. The workman hangs his clothes on the rack, pulls it to the ceiling, and locks the suspension. Clothes are thus aired when not in use.

Many owners prefer to have washing facilities in the locker room rather than in toilet rooms. If this is done, arrange basins in double rows, back to back if possible, with lockers facing them and a sufficiently wide aisle between lockers and basins. This will prevent confusion when the men come in in the morning and leave at night.

No Dark Corners

Provide adequate artificial light, with the lights located so that there will be no dark corners into which refuse may be thrown.

Heat toilet and locker rooms to a comfortable temperature in cold weather. When there are no shower baths, the temperature may be somewhat lower—55 degrees Fahrenheit is the permissible minimum.

As a general rule, direct heating with cast-iron radiators fastened to the walls slightly above the floor level is satisfactory, even though the main plant is heated by indirect or hot blast system. Arrange the system so that the heat may be kept on in cold weather at night over week-ends, and during shutdowns.

Maintenance

Locker and toilet rooms should be supervised and maintained with the same care as any other section of the factory. Designate someone, preferably of the labor gang, to care for these facilities. It will be his duty to see that they are kept clean and properly ventilated. He will note and report leaky faucets, clogged drains, closets, or urinals, indications of rust in toilet partitions, or any other faults requiring attention.

Once a month, preferably oftener, have the head of the maintenance crew inspect toilet and locker rooms for major defects, for repainting or any other necessary maintenance work that may have escaped the attention of the custodian.

In general, if care is exercised in selecting the location, arrangement, material, and equipment best adapted for the particular type of industry, class of labor, and kind of product, the toilet, wash, and locker rooms in any plant may be installed or improved at reasonable cost. If properly supervised and maintained, they will pay real dividends.

IN recent years many owners have found that good locker and washroom accommodations represent a decrease in the cost of manufactured articles because of reduction in labor turnover. As a general rule, labor is not so much concerned with hard work as with pay received and working conditions. In any industrial plant, locker and washrooms should be given every consideration. As much thought should be spent in determining proper location, size, and equipment, as is given other plant-operation details

HEATING AND VENTILATING

IN A FAIR proportion of industrial plants it will be found advisable to remodel the heating and ventilating system in order to incorporate improvements that have come into use. In other plants only simple repairing and overhauls are necessary for economical operation.

For any steam heating system, first determine whether or not the steam circulates properly. If certain radiators or coils are hard to heat, or parts of the system are noisy, the underlying causes will be failure to remove the air from the system quickly and completely, and failure to drain off the water of condensation as fast as it forms.

In most systems that rely on air valves, it will be advisable to install new valves if the old ones have been in use since the beginning of the depression. There is no economy in cheap air valves; in making replacements only the best grade should be installed.

What to Inspect

The larger and particularly the more modern steam heating systems are of the two-pipe vacuum return type and do not require air valves. Periodically open and inspect vacuum return traps connected to the outlets of the radiators. After the dirt has been cleaned out of the body and around the valve seat, take the traps to the bench and test them individually with low-pressure steam to see if they close tightly when steam is applied, and open promptly when filled with water.

Vacuum pumps should be given a routine overhauling every few years to avoid ineffective operation and waste of power, as well as the possibility of breakdown in cold weather. Since most vacuum heating pumps of the electric motor driven type are complicated and beyond the scope of the ordinary private machine shop, it is advisable to have them reconditioned by the manufacturer.

In adjusting the average straight vacuum heating system, the best results will be obtained if only sufficient vacuum is carried to secure circulation. Excessive vacuum may often interfere with proper trap and valve operation.

To eliminate banging, go over the supply and return piping with a spirit level and regrade it properly toward the drip points. Reset loosened supports. In gravity return systems it is necessary that drip points be located high enough above the water line of the boiler that the gravity head back to the boiler will be not less than the equivalent of the friction loss in the steam piping from boiler to drip point.

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Check valves in gravity return lines at the boilers frequently stick, and may advantageously be replaced with a Hartford loop on each boiler. In regrading, particular attention should be given to long heating coils made up of pipes connected by headers or return bends. Frequently they will be found to have a low point near the middle of the length, resulting in noisy operation and sluggish action.

Remove emergency drip connections installed as temporary expedients and which may allow the returns to run to waste. Make the necessary changes in piping to permit the recovery of all returns. Eliminate also live steam connections to the heating system taken from high-pressure lines to help out sluggish portions of the heating system. Heat units will be conserved, money saved.

Remember Unit Heaters

Where exhaust steam from engines or turbines is available, see that no live steam is being used for heating or process when exhaust steam could just as well be used.

Where old radiation and piping are to be replaced or where new radiation is to be installed in additions or in new buildings unit heaters should be borne in mind.

The floor type of unit heater usually can be placed against a wall or partition, alongside an aisle, or in some other location where it will not obstruct operations. It takes in cold air from the floor, heats it, and discharges it upward or outward above headroom.

The floor-type heater may have several nozzles which can be set to discharge the heated air in the desired directions. For heating large spaces, nozzles may be arranged to discharge the heated air just above headroom with sufficient velocity to secure even temperatures at distances as great as 100 feet.

The suspended type of unit heater may be used with good results in a wide range of applications. It is quite popular in laundries, garages, and heavy machine shops, shipping and receiving rooms, and many other locations. Obviously it can be applied where no form of floor obstruction can be tolerated, and where heat from direct radiation would interfere with operations or cause damage to stock or materials. Some of the smaller suspended heaters are so light that they need no support other than the piping connections which supply them with steam.

Temperature Control

Control of room temperature is easily accomplished when unit heaters are used, because the heater gives off only 10 or 15 per cent of its maximum amount of heat when its motor driven fan is shut down. The motor can be started and stopped by a mercoid thermostatic switch, with control effective to a tolerance of two degrees. For a small amount of heat at night steam may be left on with motors switched off.

In general, the cost of installing unit heaters will not be greater than the cost of installing direct radiation, and in some cases it may be considerably less, depending on how much piping may be saved by the use of a few unit heaters instead of a larger number of direct radiators usually required.

No Need to Waste Heat

Ordinary heating systems usually are designed to give 70 degrees in the coldest weather to which the locality is subject. Such minimum temperatures may not occur on a dozen days during the average winter, and at all other times it is likely that the premises may be wastefully and uncomfortably overheated unless some special means of control is provided. With hot water heating, the temperature of the water can be controlled readily and it is relatively

easy to regulate the hot air temperature in a blast system of hot air heating.

In the past few years, control methods suited for the regulation of the heat emitted by direct steam radiation have been brought to a high state of perfection; they are coming into wide use. In addition to increasing the comfort of personnel they permit fuel savings which may reach 25 or 30 per cent.

Controlling Steam Heat

At present, several types are in use. In some, the steam pressure or the vacuum or both may be varied to suit the weather conditions, so that in mild weather, under a high vacuum, the radiators may be filled with steam at a temperature as low as 165 degrees.

Other systems rely on an orifice plate placed in the inlet of each radiator and of such a size that the maximum pressure used will force through the orifice just enough steam to completely fill the radiator; in mild weather, with reduced pressure, the radiator will be only partially heated.

Still other control systems admit steam to the heating mains intermittently by cycles, the cycles being varied to suit the weather, either automatically or manually. In such a system, during moderate weather, steam might be admitted for five minutes and shut off for the next ten minutes, and so on.

All of these temperature control systems may be arranged for manual operation, and ingenious automatic devices are available which will vary the amount of heat to suit weather conditions, making use of special indoor and outdoor thermostats, some of which even take account of the effect of sun and wind in performing their functions.

Zone Control

Large buildings may advantageously be divided into various zones for heat control, so that the more exposed portions may be given more heat than those which get more sun or are protected from the wind.

Separate control of individual radiators can be accomplished either by the use of self-contained thermostatic radiator valves or by the use of room thermostats energized electrically or by compressed air from a central source.

Nowadays modernization of an existing ventilating system always brings up the subject of air conditioning. Many industrial processes have long been dependent on control of humidity between close limits. Others require either extreme moisture or extreme dryness. Still other operations would have to be discontinued in warm weather if mechanical refrigeration were not available.

Real air conditioning implies complete control of temperature and humidity under all variations of outside conditions.

For merely increasing the comfort of those who work in office or workrooms during hot weather, the simplest apparatus will be found sufficient. The air may be cooled and dried at a central point where all mechanical apparatus is concentrated and distributed thence by ducts to the desired points, or unit coolers may be located in the areas to be cooled.

The development of such unit coolers has been carried to a point where most satisfactory results may be obtained under conditions not suited to the installation of a central cooling system. Such unit coolers may be connected to the heating system and arranged to heat the rooms in cold weather.

In any program of rehabilitation or modernization of heating and ventilating equipment, the first procedure should be to make a careful survey of the existing installation.

In some plants simple repairing and overhauling only will be necessary. In other plants the system should be remodeled extensively to take advantage of the many improvements that have been developed recently.

There is nothing to be gained by undertaking the rehabilitation of heating and ventilating equipment without systematic planning. Without a comprehensive plan there is grave risk that one revision will lead to another, with the final result that a normally inexpensive program will result in unnecessarily high costs

The actual cooling of air is accomplished by a refrigeration process of one kind or another involving evaporation or absorption. The compression system is still the one most commonly used, in connection with ammonia, carbon dioxide, or one of the many newer refrigerants which have been developed and popularized in recent years.

The steam jet system is rapidly becoming common and should be given serious consideration in any proposed installation.

In cities, the question of cooling water for refrigeration is becoming a serious consideration, and cooling towers which permit the water to be used over and over will be of increasing importance. In some cities even the digging of wells for obtaining cooling water has already been forbidden, since such water is likely to be used only once and then wasted.

Saving by Insulating

Intelligent use of modern insulating materials will permit great savings in the cost of heating, but even greater savings in the cost of cooling a building. Without adequately insulated construction, the load on the cooling equipment, and consequently the required size and cost of the equipment may be excessive.

Exposed roofs are one of the greatest sources of loss, and even in existing structures the insulating of the roof may be a comparatively cheap and simple operation. Sidewalls are usually more difficult to insulate after the original construction is completed. The effect of sunshine on such walls, which is an important factor in the heat transmission, may be minimized, however, by the use of suitable awnings and window shades.

To Avoid the Extras

Floors, ceilings, and wall between cooled and uncooled portions of the building should be insulated, and any sources of heat such as hot piping passing through cooled spaces should be given particular treatment. It should be borne in mind that cooling is accomplished only by the use of considerable amounts of power, and that any saving in heat losses will be reflected in decreased operating cost.

The revamping of heating and ventilating equipment for any given building should be narrowed down to include only the problems at hand. If complete plans and specifications for the work are prepared in advance, bids can be secured on the basis of fair competition. Most of the extras that cause conflicts between owner and contractor when alterations to an existing installation are involved can be avoided.

PIPING AND PLUMBING

THE GREATEST enemies of ordinary pipe are corrosion, freezing, and improper anchorages and joints to care for expansion and contraction.

Corrosion is almost impossible to eliminate except by the use of special alloys, copper, or brass. Pipes rust on both interior and exterior surfaces; so their strength and life may diminish at a twofold pace. Exterior surfaces may, however, be preserved indefinitely by protective coatings, such as oil or asphalt paints, and enamels. Any material that will keep out moisture will serve the purpose. For proper protection the entire exterior surface must be covered; even a pinhole will allow a pipe to leak. Special paints must be used on pipes that are hot, or that may "sweat." If the wrong paint is used it will be money lost.

Locate in Dry Places

Wherever possible piping should be located in a dry area, protected from moisture, and be made easily accessible. Shafts for vertical rises and tunnels for horizontal runs meet these conditions where many lines are to be run.

Freezing of pipe may cause considerable damage and loss. In heated buildings protection is easily secured by thermostatic control set to turn the heat on automatically at about 40 deg. F. and off at 50 deg. F., if the building is unoccupied.

Hair felt and asbestos coverings also afford protection, but when extreme cold is of long duration they are inadequate.

Bleeders can be installed at the ends of mains and run to drains, or valves at the ends of branches can be left "cracked." Lines that freeze may not break if found in time, but the stoppage may cause serious delays.

Heating of large mains or tanks by convection currents set up by heaters is successfully employed with sprinkler and standpipe system gravity tanks. It is important to remember that even a very short length of pipe, or a valve, if not sufficiently protected may freeze, causing a constriction in the pipeline that may stop the flow or destroy the convection currents. From this point freezing can then spread rapidly.

Various means have been used for thawing frozen pipes, but one of the quickest and most efficient involves passing an electric current of suitable strength through them at the frozen areas. In this way sections can quickly be cleared enough to allow flow of the liquid in the pipe, which will then wear away the ice, if given a little time.

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Source of current may be a low-voltage transformer or an arc welding generator. It is difficult to specify the strength of current to be used for different sizes of pipe because such factors as presence or absence of insulation, location, and so on, affect the loss of heat from the pipe and hence the amount required to thaw it. When experience is lacking it is usually necessary to determine the proper current value by cut-and-try methods.

Improper anchorages and allowances for expansion in pipe lines lead to distortion in proportion to the temperature change of the contents. This sets up incalculable stresses for which the line cannot be designed and results in strained and leaky joints, which may cause serious failure to the line as well as damage to the adjacent areas.

Need for Free Circulation

With this brief background it can be appreciated that the importance of paying attention to details in the inspection and maintenance of all pipe lines cannot be over-stressed. The efficiency of a line depends upon free circulation throughout all parts; if this is prevented or retarded the system cannot perform the services demanded of it.

One of the prime objects of an inspection is checking for leaks and their causes. Leaks may be caused by corroded piping, improperly wiped joints, breaks or cracks due to freezing, improper hanging, or lack of provision for expansion and contraction. When all leaks have been cleared up, the next step is to determine and take whatever action is necessary to prevent other or further deterioration. Practically, this means painting and covering the lines. Piping should be painted even though it is to be covered.

Best Way to Inspect

To facilitate inspection of pipe lines and systems it is best to take each type separately, following through from street mains to the extreme ends of the system. In this way all defects common to general piping, and details pertinent to the system under inspection, can more easily be tabulated and fewer items will escape attention. In most plants there are five main types or systems of piping (water supply, sanitation, sprinkler system, process services, and heating) and although some of these systems are continuously in use a thorough and systematic inspection should be made at least once a year, preferably twice —in spring and fall.

The table shows the chief elements

Color Identification of Piping Systems

A standard scheme approved by the ASA as American Recommended Practice is based on the general principle that the pipes of a specific system should be color-marked to indicate, first, the class of material to which the contents belongs. The marking also tells whether the material is safe or unsafe. These classes, with their characteristic colors and letter symbols, are:

F—*Fire protection*—Red
D—*Dangerous material*—Yellow
S—*Safe material*—Green
P—*Protective material* — Bright blue
V—*Extra valuable material*—Deep purple.

The basic color may be applied over the entire system, or in wide bands placed at intervals throughout the system, preferably near valves and other important places. More detailed identification may be obtained by adding stripes of any desired color at the edges of the main band, or by stenciling letters, words, or figures on it.

of these systems, and the conditions to be checked.

In addition to pipe lines there are two important complementary items that must be given adequate attention. These are gravity tanks for sprinklers, standpipes and, oftentimes, water supply and process lines, and the boiler room, which supplies steam or hot water for heating and process work.

Tanks, Risers, Circulating Lines

The gravity tank, risers, and circulating lines should be inspected to determine need for painting, condition of covering, and existence of leaks at the same time as all pipe lines. Exposed to the elements as they are, deterioration may be rapid and if any failure results the entire system is crippled. Also, inspect overflow, drain, and limit floats of the tanks to prevent waste of water and unnecessary operation of pumps and motors.

Check the riser covering at the under side of the tanks; if the covering slumps a short length of exposed pipe will be left which will freeze quickly, destroying the effect of the tank heaters. One way to prevent this is to put on an additional sleeve of covering material over the main covering, attached to the tank itself and extending downward about 18 inches. If the main covering slips the pipes will still be protected.

In the tank house the heater should be cleaned the same as any boiler and checked for leaks, condition of covering, grates, drains. All valves should be checked, pumps packed if necessary, bases repaired so that pumps and motors are mounted solidly and do not vibrate, thermometers and gages checked for accuracy, and alarm valves inspected for operation.

Boiler Tubes

Boiler tubes should be tested for leaks and weakening from corrosion. A hydrostatic test will show up defects in the shell, crown sheet, gages, relief or blowdown valves, and other accessories. Leaking tubes can quickly be plugged, but too many will seriously impair boiler efficiency. Renew all plugged tubes as soon as possible. Check for warped or burned-out grates.

If oil burners are used check for possible saving in fuel by proper mixture of oil and air, by adjustment of automatic controls and of flame.

Keep the boiler free from soot and dust. If necessary, treat the feed water to prevent encrusting of heating surfaces, which seriously interferes with boiler efficiency.

Check all meters, lines, gages, pumps and motors, foundations, automatic controls, and other equipment in the boiler room. The engineer in charge is in every-day contact with all of these items and should be the first to see defects and report them. He should list and report all repairs that are needed but not urgent, and in general be familiar with the condition of every item of equipment, pipe lines, and so on, in his care. It will frequently be possible for him to show where and how savings can be made by changes in location or character of equipment.

Simple Rules to Follow

If these simple rules are followed, maintenance costs will be kept at a minimum:

1. Keep pipe lines painted at all times; this prevents rusting and adds to the appearance.

2. Keep all hangers, anchors, and expansion joints in order to prevent movement of pipe lines, which tends to open joints or split pipes and fittings.

3. Never allow a leak to continue; it is almost certain to become worse and cause damage and delay.

4. Keep all pipe covering in good order; once it starts to disintegrate, its insulation value diminishes and the appearance becomes unsightly.

Points to Check in Piping System

Item	*Check for*
Meters	Accuracy, broken dials, hands, seals, leaks, supports, and need for protection to prevent freezing.
Bypasses	Painting, leaks, valve packing, supports.
Control valves	Packing, condition of valve seats, leaks at connections.
Risers	Painting, leaks, condition of floor clamps, hangers, expansion joints, sleeves and curbs, guards, covering.
Soil and vent stacks	Painting, leaks, condition of floor clamps, hangers, sleeves and curbs, guards.
Mains	Painting, leaks, slope, condition of hangers, wall sleeves, expansion joints, covering.
Horizontal runs	Painting, leaks, slope, condition of hangers, sleeves.
Branches	Painting, leaks, slope, condition of hangers, sleeves, covering guards.
Hangers	Fastening, adjustment for slope of pipe, proper spacing and strength, covering on lines at their location, painting.
Covering	Painting, need for canvas or metal protection, sewing or bands' looseness, holes, general adequacy.
Expansion joints	Painting, possible covering, leaks, packing, alignment, anchorage or supports.
Sleeves and curbs	Stability, packing around pipes, height of sleeve top or curb above floor, pointing at exterior of sleeves in floors to prevent leaks.
Hand valves	Possible covering, condition of seats, packing, wheels, stems, presence of leaks, cracks in body.
Toilet flush valves	Pipe sizes, leaks, need for adjustment.
Traps and seals	Painting, possible covering, leaks, cracks, stoppage, supports.
Fixtures	Cleanliness, cracks, fastenings, leaks at connections.
Sprinkler heads	Cleanliness of fuse, melting points of fuses near heaters or hot pipes, correct number and location, protection from damage or freezing, need for painting of body.
Radiators	Painting, leaks, slope, condition of hangers and supports.
Heaters	Cleanliness, condition of fins, motors and wiring, hangers, presence of leaks.
Air valves	Leaks, need for cleaning, proper size, number and location.
Swing check valves	Leaks, proper size and location, cracks in body, condition of seats.
Traps	Painting, leaks, internal cleanliness, condition of seats, coils, etc.
Thermostats	Proper temperature ranges, fastening, proper location, need for protection from damage, condition of connections.

FACTORY MANAGEMENT and MAINTENANCE

BUILDING MAINTENANCE CHECK CHART

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ANY PHYSICAL inventory is facilitated by the use of a combination reminder and checking system. This chart constitutes such a system for use in making a physical inventory of the condition of buildings, and preparing a program of building maintenance and rehabilitation.

In scope the chart covers the major items of building maintenance, no matter what the industry. Items shown on the chart but that are not parts of your buildings can be disregarded; likewise items can be added if necessary.

Yards and Yard Equipment

Grounds (1A)

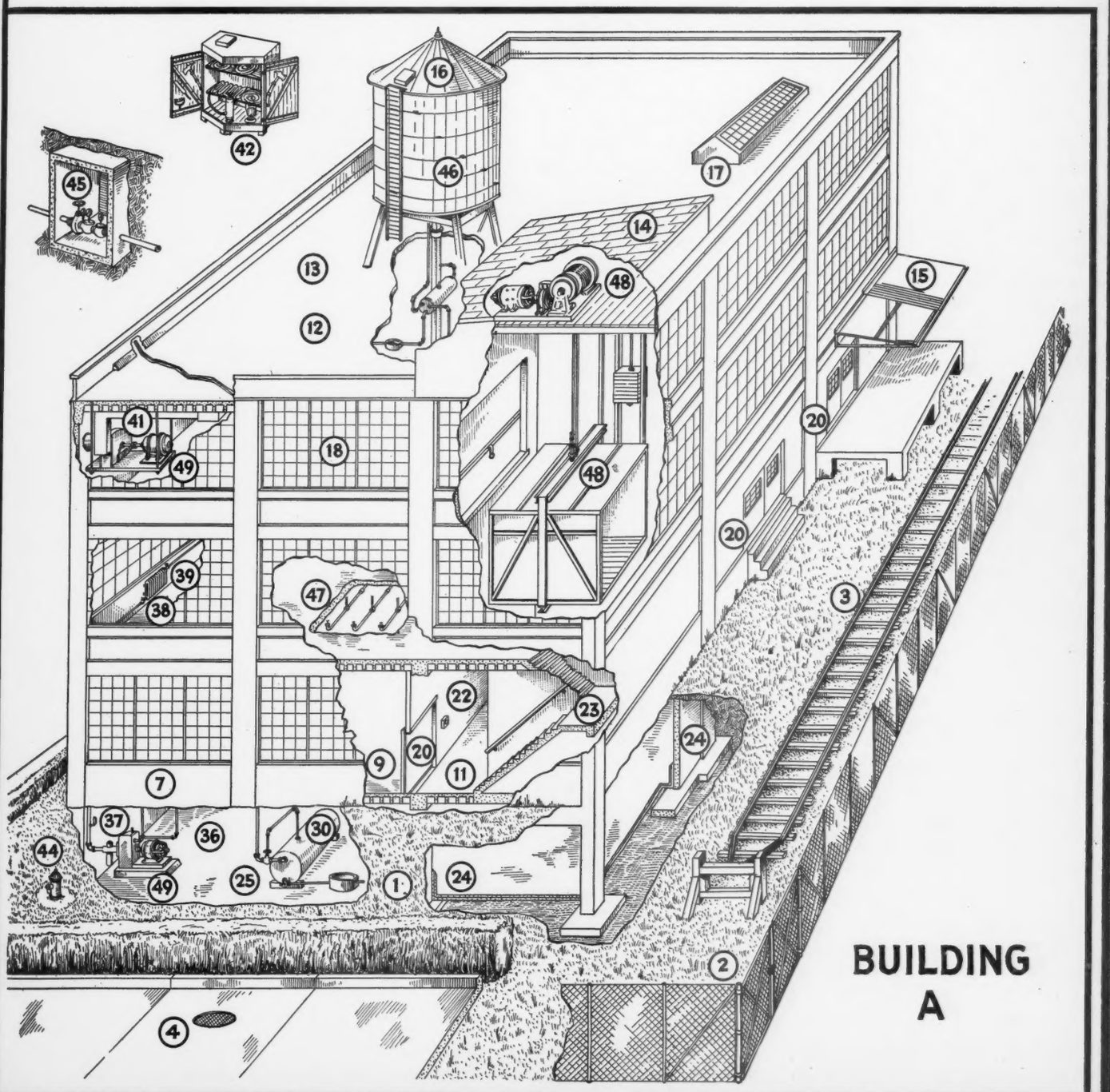
Give general inspection monthly.
Determine need for patching or rebuilding roads and walks.
Check grass for reseeding or resodding.
Check hedge for replacements.
Check grounds for low spots.

Fences (2A)

Inspect semi-annually, repair as needed.
Check gates for hinge replacement.
Check painting.
Check corrosion and rot at base of posts.
Check corner braces.
Check barbed wire guards.
See that gates swing or slide freely.
Check condition of gate locks and latches.

Railroad Tracks and Trestles (3A)

Inspect once a month and repair as needed.
Check for loose spikes and rail joints.



Check ties for rot and loose foundations.
Check rail gage.
Check bents and stringers for failure and dry rot.
Check need for ballasting.

Pavements, Curbs, Gutters, Storm Sewers (4A)

Make general inspection of curbs, gutters, and sewers monthly.
Are sewers and manholes clear?
Make general inspection of pavements weekly.
Are there holes or ruts?
Check drainage and low spots.

Buildings

Frames, Steel (5B)

Inspect semi-annually.
Determine need for painting.
Where support for traveling cranes is integral with building structure, check rivet connections.
Check column bases.

Frames, Wood (6B)

Inspect yearly.
Check for dry rot in sills and foot of columns.
Check for overloading.

Frames, Concrete (7A)

Inspect yearly.
Check for cracks, checks, and spalling of columns and girders.
Check beams for spalling and shear cracks from overloading.
Check window sills.

Frames, Brick (8B)

Inspect yearly.
Check for loose brick.
Check for loose mortar joints.
Is pointing up needed?

Floors, General (9A and 9B)

Inspect weekly to quarterly, depending on construction and use.
Check for loading.
Check beam system for strength (semi-annually).

Floors, Wood (10B)

Check joists, sleepers, and beams for dry rot (semi-annually).
Check for loose or broken boards.

Floors, Concrete (11A and 11B)

Do depressions need filling?
Is dust preventive treatment needed?
Do sections or complete floors need replacement?

Roofs, General (12A and 12B)

Inspect quarterly.
Are roofs swept? Gutters, eaves, and roof drains clean?
Check guy wires.
Check flashing.

Roofs, Asphalt, Pitch, or Tar (Built-up Roofs) (13A and 13B)

Check for blisters or cracks.
Check for breaking of bond with deck or layers below.

Roofs, Slate (14A)

Check for loose and cracked slates.

Roofs, Corrugated Iron and Steel (15A)

Is paint needed?
Check corrosion of fasteners and around fastener holes.

Roofs, Roll (16A)

Check for cracks.
Inspect for loosening at overlap.

Roofs, Tile or Cement Tile (not illustrated)

Check for disintegration of cement or tile through checks and cracks.

Sash and Skylights, General (17A and 17B)

Inspect quarterly and after heavy storms.
Check glazing, watching for cracked and loose putty.
Check for broken or cracked panes.
Has wire glass been installed on sides exposed to street or road or adjacent to serious fire hazard?

Sash, Steel (18A and 18B)

Do ventilators close tight?
Are perimeters well caulked?
Check for corrosion at sills.

Sash, Wood (19B)

Check cords and weights.
Check stops, stiles, and rails.
Check frame and sash for dry rot.
Check for free operation.
Check fasteners.

Doors and Partitions, General (20A and 20B)

Inspect weekly for repairs.
Check for loose hinges.
Is varnish or paint needed?
Check for weather beating.
Check jambs for caulking.
Do swinging doors have wire glass vision panels?
Are glass replacements needed?
Do doors hang properly?

Doors, Fire (21B)

Check metal covering.
Check counterweights.
Check fusible links.
Check operating mechanism.

Partitions (22A and 22B)

Are repairs and painting needed?

Stairs (23A)

Are stairs well lighted?
Are handrails tight and smooth?
Check for wear on treads and nosing.
Check for smooth or slippery treads.
Check for rust or rot and need for paint.
Check fire escape operating mechanism.

Waterproofing (24A)

Check foundation walls and floors for cracks and sweating. (Watch closely during periods of high water or excessive rainfall).
Is caulking or other repairing needed?
Is treatment of exterior or interior with waterproofing compound needed?

Building Equipment

Sanitation, General (25A and 25B)

Check all fixtures, valves, and drains for stoppages, leaks, replacements.
Check for chances of freezing.

Wash Fountains, Lavatories, Shower Baths, Sinks (26B)

Check hot and cold water and mixing valves; also waste traps.

Toilets, Urinals (27B)

Check flush valves, tanks, float valves, drains, and seats.
Check doors and hardware. Is paint needed?

Drinking Fountains (28B)

Check water valves, drains, and traps.

Floor Drains (29B)

Check traps and cover plates.

Water Heater (30A)

Check for lime deposit.
Check temperature and temperature control.
Check steam traps.

Lockers (31B)

Is paint needed?

Lighting, General (32B)

Check required illumination in foot-candles.
Check condition of cords, sockets, plugs, receptacles, and shades.
Check pipe supports.

Lighting, Transformers (33B)

Test insulation—primary to secondary to ground.
Test oil for moisture.
Check permanent ground.

Lighting, Panel Boxes and Fuses (34B)

Inspect clips.
Check for proper fusing.
Check panel for permanent ground.

Lighting, Distribution (35B)

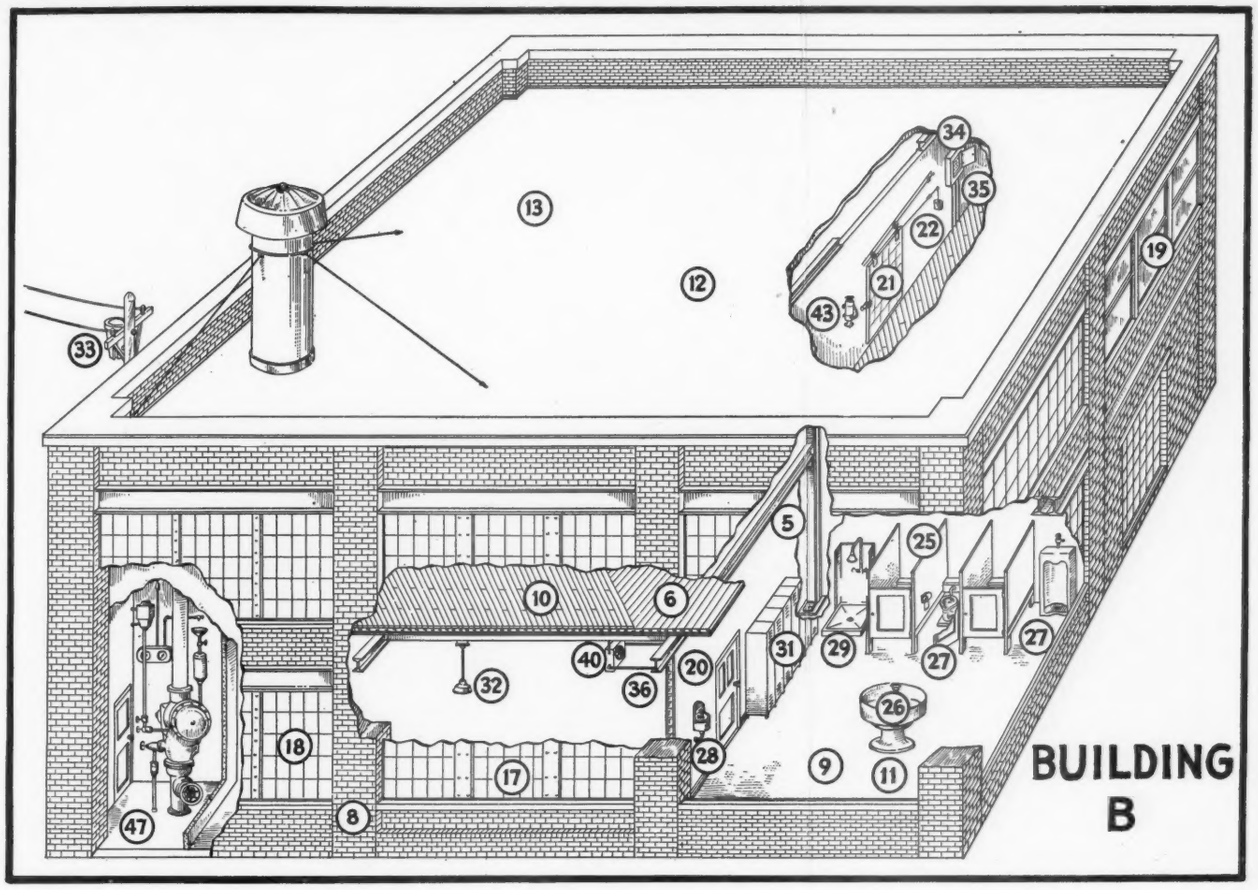
Make insulation resistance test.
Check circuits for voltage drop.
Check conduit for permanent ground.

Heating, General (36A and 36B)

Make yearly inspection of heating system during summer months with thorough repairs to every item.

Heating, Vacuum Pumps (37A)

Check condition of all parts.



Heating, Mains and Returns (38A)

Check for leaks.
Check covering.
Check grades.
Check valves and traps.

Heating, Radiators (39A)

Check valves.

Heating, Unit Heaters (40B)

Check motors (see 49).
Check traps and valves.

Ventilating Equipment (41A)

Check fan blades.
Check end thrust, balance, and coupling.
Check connections and gates in duct system for leaks.
Check air washers.
Inspect motor (see 49).

Fire Protection, Hose (42A)

Inspect all inside hose and connections.
Test rubber-lined hose under full plant water pressure for 24 hours.
Check all couplings and see that threads and swivels are not damaged.
Check hose gaskets for replacement.
Keep post indicator valves and pit covers free and hydrants easily accessible.

Fire Protection, Extinguishers (43B)

Do any extinguishers need servicing?

Fire Protection, Fire Doors (See 21B)

Fire Protection, Hydrants (44A)

Check butts for damaged threads.
Check valves for free operation.

Fire Protection, Check Valves (45A)

Are valves tight?
Are pits dry?

Fire Protection, Gravity Water Tanks (46A)

Inspect tank, tower piping, valves, heating system, and accessories.
Check expansion joint for binding and leaks.
Is paint needed?
Check heater trap.
Test relief valve.

Fire Protection, Sprinklers (47A and 47B)

Test all electric alarms and water motor gongs.
Check annunciators and all circuits.
Check air pressure in dry-pipe system.
Check dry-pipe valve for leaks by clapper.
Check sprinklers for leaks from defective heads, piping, bad fittings, missing or broken hangers.
Check lines for proper grade on dry systems.
Do all heads have fusing point 50 deg. F. higher than maximum room temperature?

Elevators (48A)

Inspect drum, crosshead, and counterweight connection.
Inspect operating cable or control switch.
Inspect all machinery, including worm gear and motor (see 49).
Inspect slack-cable device and governor cable.
Inspect all electrical equipment and limit switches, control, solenoid and brakes, board and contacts.
Inspect shaft and car.
Inspect doors and door-operating mechanism; check door switch.
Inspect counterweight socket connection and bumpers.
Check signal system.
Check for worn bearings, loose bolts, poor connections, dirty motor windings, oil ring location, brush setting, packing gland, alignment of worm gear and clearance, thrust-bearing end play.
Check wear on cable drum grooves.
Check brake lining for wear and clearance.
Check cable for broken strands. If seven or more wires are broken in any one section renewal should be made at once.
Check lock nuts or cotter keys on car-beam spring yoke.
Check track alignment, bolts, matching of joints.
Check car for squareness and level of floor.
Check shoes for proper track clearance.
Check setting of safety dogs.
Check hydraulic door. Check for amount of solution.

Motors (49A)

Check air gap.
Make insulation resistance test.
Check permanent ground.
Check bearings.
Check control contacts.
Check overload relays and no-voltage release.

	Surface	Defects on Surfaces		Reason for Defects		Rem
		New	Old	New	Old	New
EXTERIOR SURFACES	STEEL	Oil or grease, mill scale	Peeling of paint; rust and scaling of metal; oil or grease		Oxidation of metal due to poor painting; loosening of mill scale; negligence in painting	
	WOOD	Dampness. Dirt spots	Blistering, peeling, wrinkling		Dampness, poor paint used, improperly applied, or too long period between applications	Allow to dry thoroughly. Bleach with oxalic acid
	CONCRETE	Porosity of surface, allowing dampness to attack steel reinforcement	Peeling of paint, absorption of moisture	Inherent nature of concrete	Surface not thoroughly dry when painted: waterproof paint has not withstood elements: insufficient paint applied	Waterproof surface
	BRICK *					
	GALVANIZED SHEET METAL	Oil and grease. Acid	Same as for steel	Due to galvanizing	Same as for steel	
INTERIOR SURFACES	STEEL	Same as for exterior steel	Same as for exterior steel		Same as for exterior steel	
	WOOD †					
	CONCRETE	Small holes; dampness	Blisters, peeling of paint; discoloration and oil spots	Lack of proper tamping when concrete was placed	Surface damp when painted; action of alkali in concrete on oil in paint; paint applied over improperly prepared surface; oxidation of oil in paint; spattering of oil from machinery	Allow to dry thoroughly before painting oil paint is to used
	BRICK **					
	PLASTER	Dampness	Same as for concrete	Not dried out	Same as for concrete	Same as for concrete
	CONCRETE FLOORS	Dampness	Paint surface worn through		Natural wear and tear	Do not apply coating on flo until it has dr thoroughly
	WOOD FLOORS	Warping, dirt spots	Paint surface worn through	Dampness	Natural wear and tear	Keep floor dry crete allow c coat with asp before laying

Note: *New* indicates surfaces not previously painted. *Old* indicates surfaces previously painted.
*Brick walls should be waterproofed to preserve surface and improve appearance. † Same

Painting Defects and Remedies

° Remedy for Defects °		° Preparation of Surface °		° Prime Coat °	
New	*Old*	*New*	*Old*	*New*	
	Paint properly, without delay, when necessary	Clean off dirt. Remove oil and grease with benzine. Remove mill scale on plates by sandblasting, or allow to weather 6 mo. then sandblast	Thoroughly chip, wirebrush, or sandblast	Red lead and linseed oil; red lead, graphite; red lead, red oxide; blue lead; coal tar base paints	Where ste cover with as for new
ow to dry oroughly. each with alic acid	Do not paint damp surfaces. Paint more often. Use proper paint	Clean off dirt	Scrape and clean. Burn off old paint if surface is wrinkled	White lead or zinc and linseed oil, linseed oil, wood stain	Spot paint paints sh surfaces
terproof rface	Properly waterproof surface	Clean and wirebrush entire surface, "V" out cracks and caulk with asphalt-base caulking compound, caulk around all window sash. Do not paint until surface has aged 1 year	Clean surface, caulk all cracks and around window sash where needed; apply 1 coat of prime paint over bad areas	Apply thin coat of wax-base, waterproof paint, or chemically compounded waterproof paint—colored if desired	Same as fo
		Same as for concrete surfaces. Where necessary point all joints with mortar.		Same as for concrete	Same as fo
	Same as for steel	Wash with vinegar or copper sulphate solution	Same as for steel	Same as for steel, but applied before erection	
	Same as for exterior steel	Same as for exterior steel	Same as for exterior steel	Same as for exterior steel except pigment content of paint may be reduced	Same as fo and redu content
w to dry out roughly be- e painting, if paint is to be ed	Do not paint on wet or damp surfaces. If oil paint is to be used allow surface to dry at least 6 months	Fill holes with paint or plaster and point cracks. Clean off dirt	Clean surface thoroughly, apply aluminum paint or shellac to oil spots, scrape off all loose paint; coat all bare spots with primer paint	Coat with oil mill white primer or casein-base paint	Mill white casein-ba aluminu surface h ously pai water pa tional lin prime pa surface w turpentin base pain
		Also paint joints with cement mortar			
e as for crete	If oil paint is to be used allow surface to dry at least 2 months	Point cracks, clean off dirt	Same as for concrete	Same as for concrete	Same as fo
ot apply any ting on floor til it has dried roughly	Use penetrating oils and not merely surface coatings	Sweep and clean surface. Allow to dry thoroughly before application of paint or filler		Penetrating oils and grease mixed with solvent and colored as desired. Primer for floor paint	
p floor dry. If placed over con- te allow concrete to dry out and t with asphalt or tar compound ore laying		Clean off dirt		Hot linseed oil; shellac, wood primer for floor paint; wood filler	Same as fo

y painted.

† Same as for exterior wood surfaces. ** Same as for concrete surfaces.

...at °	° Second Coat °		° Finish Coat °	
Old	New	Old	New	Old
...ere steel is exposed, ...er with prime paints ...or new surfaces	Same as prime, but reduce pigment content	Not needed unless old paint has deteriorated badly	Same as second coat; coal tar base paint; aluminum paint	Same as for new surfaces
...t paint with prime ...nts shown for new ...faces	White lead or zinc and linseed oil. Stain	Usually not needed. Same as for new	White lead, and/or zinc and linseed oil. Varnish	Same as for new
...e as for new	Same as for prime coat	Generally not needed unless surface is in poor condition	Apply heavier coat of same paint as used for prime coat. If uniform finish is not obtained, apply additional coat of finish to dead areas	Same as for new
...e as for concrete	Generally not needed	Generally not needed	Same as for concrete	Same as for concrete
	Same as for steel	Same as for steel	Same as for steel	Same as for steel
...e as for exterior steel ...d reduce pigment ...ntent	Generally not needed	Generally not needed	Same as for exterior steel	Same as for exterior steel
...white prime paint, ...ein-base paint, or ...minum paint. If ...face had been previ...sly painted with cold ...ter paint, add addi...nal linseed oil to ...me paint, or coat ...face with oil and ...rpentine for casein...se paint			Oil mill white using flat, egg-shell or gloss finish as desired. Casein base paint if needed	Same as for new
...e as for concrete	Same as for concrete	Same as for concrete	Same as for concrete	Same as for concrete
	Same as prime coat		If oils and gums are used, apply 3 coats floor paint	Same as for new
...e as for new	Hot linseed oil; shellac; stain	Same as for new, if needed	Hot linseed oil; shellac, floor paint; varnish	Same as for new

Prepared by L. E. DRIVER *as a part of the chapter "Painting," see page S25*

❖

Overhead Expense Control through STANDARD COSTS *and Flexible Budgets*

❖

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The time has probably arrived for less poker and more chess in business management.—William H. Lough

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Overhead Expense

A dominant element in manufacturing costs

ARE the overhead expenses of your company distributed *and controlled* — or just distributed? Your answer to this question indicates whether or not you are taking advantage of at least 20 per cent possible savings in your overhead expenses.

Most factory accounting procedure of today embraces fairly satisfactory methods for the distribution of overhead expenses. On the other hand, very little indeed has been done to budget and thus control these expenses.

Under a system of standard costs and flexible budgets the control of overheads is definitely achieved; and it is the purpose of this paper to point out the advantages and the underlying methods that come with this latest development in costing and budgeting.

Labor and Materials Controlled

Through the application of time studies, *the setting of standard rates* for direct labor has reached a degree of proficiency in which that element of cost is quite satisfactorily controlled. Likewise with materials. The advances made in analyzing market trends and the progress made in engineers' estimates of consumption requirements have placed *the setting of standards for materials* upon a sound basis.

Overhead Tacked On

When it comes to *standards for overhead expense*, however, we still flounder in the open seas. There is not much in the way of literature on the subject, while research in industry reveals very little indeed that shows an adequate scientific treatment of the problem.

There is a reason for this lag in setting standards for overhead expense. In the early days of the science of cost accounting, direct labor and direct material were by far the major elements in manufacturing costs; in addition, direct costs were easy to observe. Overhead expenses, on the other hand, were considered of minor importance and were treated as an elusive cost element to be "tacked on" after the compilation of direct costs had been made. In short, the cost accounting procedure of today still reflects these influences and practices coming from earlier industrial periods.

But industrial change comes quickly! The modern shift from manual to machine production which characterizes all industry; the sudden growth of high-speed tools; the increased speed of flow of work through the plant; the recent trend toward standardization and mass production—all bear heavily upon the respective importance of the different cost elements. These fundamental industrial changes mean an ever-increasing proportion of investment cost, supervision, maintenance, technical salaries, power, clerical expense, and the like. *They mean that overhead expense today is rapidly becoming the dominant element in manufacturing costs. It is this newer condition that justifies this treatise.*

No Theories, No Formulas

A definite attempt has been made to keep this paper practical. General theories and highly involved formulas have been left out of the discussion. The principles, methods, and advantages portrayed are found in plants with which the author has direct and intimate contacts. He lays no claim to the original developments of standard costs and flexible budgets, but rather attempts to bring to the reader a description of the principles and point out their practical application in actual manufacturing establishments.

THE WHOLE SPIRIT of standard costs and the flexible budget is based on the psychological power of definite goals or bogies. They redeem industrial policy from hunches and guesswork, and place it on a firm basis of realities and factual control. Probably no one has put it more clearly than John Dewey when he wrote:

"Men don't shoot because targets exist, but they set up targets in order that shooting may be more effective."

Four Basic Principles

First, fix responsibility

IF OVERHEAD expenses are to be effectively and adequately controlled, four fundamental principles are necessary:

1. Definite named responsibility must be established for every overhead item found in the manufacturing enterprise.

2. Overhead expenses must be definitely related to specific amounts of measured production.

3. Flexible budgets must be established that set forth the amounts of overhead expense for given volumes of output.

4. Specific percentages of the savings achieved through beating these budgets should be shared as a spurring incentive with those responsible for the success accomplished.

These four principles should be kept in mind constantly by the reader as he proceeds through this article.

Direct and Prorated Expenses

What to charge; what to spread

TO MAKE our approach definitely practical, let us take a specific plant which we will call The Glenora Sign Company. This plant makes advertising signs for the oil industry. By observing the plant layout in Figure 1 it is noted that there are but seven production sections or cost centers. The total number of people employed seldom exceeds 450 persons.

The production departments are Cutting, Rim-Bending, Threading, Tapping, Assembly, Painting, and Packing.

Each of the above sections has a list of expenses known as the *direct* overhead expenses. Cost Center D (Tapping), for instance, has those shown in Table I.

TABLE I

Direct Expenses Cost Center D

1. Foreman
2. Asst. Foreman
3. Helpers
4. Defective Work
5. Mfg. Supplies
6. Tools
7. Overtime Bonus

In addition to these direct expenses there is a second group known as the general or *prorated* expenses. They include items that are not chargeable directly to the cost center. They are, however, spread to the cost centers on a prorated basis and solely for cost purposes. The prorated expenses of the Glenora plant are shown in Table II.

With this division of overheads between direct and prorated, let us develop the importance of measuring the normal capacity of the plant and the relation of overhead expense to that capacity.

TABLE II

General or Prorated Expenses

1. Superintendent
2. Assistant Superintendent
3. Engineering
4. Factory Accounting
5. Inspection
6. Heat, Power, and Light
7. Storeroom
8. Receiving Department
9. Shipping Department
10. Toolroom
11. Watchman
12. Repairs and Maintenance
13. Insurance and Taxes
14. Depreciation on Buildings
15. Depreciation on Machinery

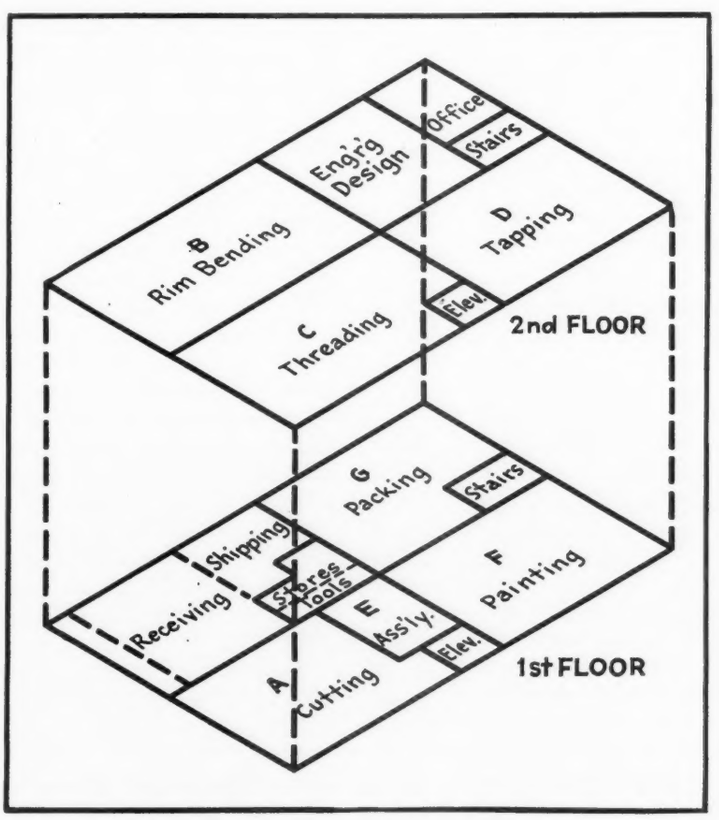

Figure 1. The mythical Glenora Sign Company has seven cost centers

Normal Capacity

On the basis of standard productive hours

NORMAL capacity might be defined as a volume of production that represents the concern's fair average output. In the company we are discussing it is based upon the number of standard productive hours needed to turn out the average sales expectancy taken over a long sweep of time—eight or ten years.

A very enlightening article on measuring normal capacity is found in the National Association of Cost Accountants bulletin of Dec. 1, 1934, written by Charles C. James.* In it Mr. James defines normal capacity as follows:

"Normal capacity is the utilization of physical plant that is necessary to meet the average commercial demands over a period of time long enough to level out the peaks which come with seasonal and cyclical variations." See Figure 2.

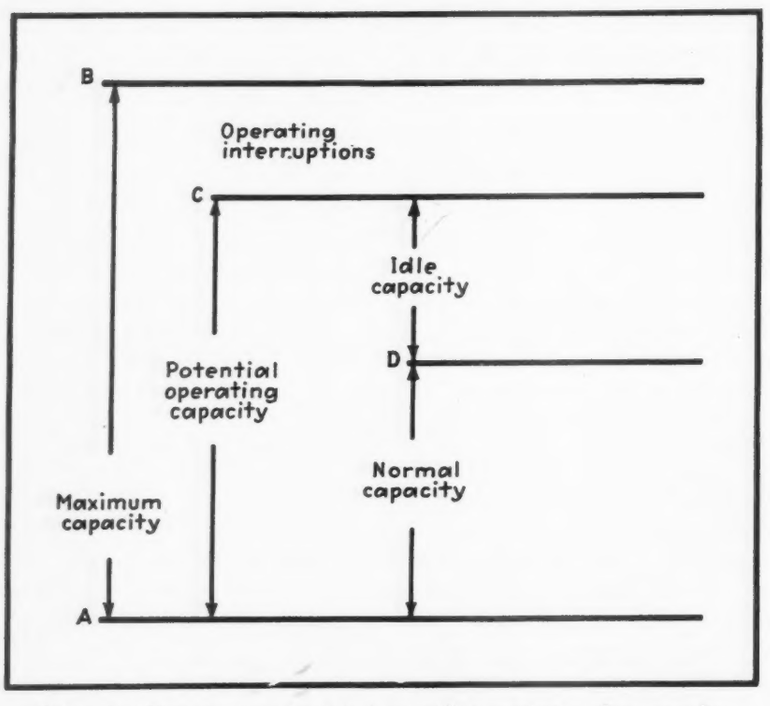

Figure 2. Illustrates how hard it is to utilize maximum plant capacity

*"Measuring Plant Capacity" by Charles C. James. Bulletin XVI, No. 7, Dec. 1, 1934, National Association of Cost Accountants, New York.

The normal capacity for each cost center and for the whole production department is stated on the basis of standard hours of direct labor. In a factory converting diversified materials into many products there is no other common unit to provide a uniform measuring stick. Therefore the *standard productive hour* is the common denominator for measuring not only normal or standard capacity but also all other amounts of capacity.

For example, Cost Center D (Tapping) has a measured performance of 3,450 standard productive hours as representing its normal capacity for a month. This number of hours represents the work of 21 direct labor employees in that section. Normal capacity is rated as 100 per cent or standard capacity.

Next consider the amount of direct expense of Cost Center D for the month. The budget for these expenses at the normal capacity of 3,450 standard productive hours is $2,530, made up of the direct overhead items indicated in Table III.

Dividing this $2,530 by the standard productive hours at normal capacity (i.e., 3,450—see Table IV), we have 73c. per hour as the standard cost rate for direct overhead expense for Cost Center D.

In addition to this budget of $2,530 for direct overhead expenses this cost center must carry its share of the prorated expenses. This prorated item amounts to $2,600 as Cost Center D's share, or 75c. per standard productive hour.

TABLE III

Budget of Direct Expenses

Cost Center D at Normal Capacity

Foreman	$200
Assistant Foreman	140
Tools	730
Helpers	300
Defective Work	500
Supplies	460
Overtime Bonus	200
	$2,530

By adding 73c. and 75c. we arrive at $1.48 as the standard cost rate for costing all overhead in Cost Center D.

The use of this one rate, $1.48, for costing the overhead in Cost Center D is the ultimate in simplicity. If production is high or low, or if production is efficient or inefficient, the same rate is used in charging the standard hours of work performed.

Detours from standards such as off-volume production, spoilage, and the like are set forth in variances which will be considered in detail later.

Before measuring these variances, however, it becomes necessary to set budgets for overhead expenses at different volumes of production. These budgets naturally differ for different volumes, and thus have gained the name of *flexible budgets.*

TABLE IV

Flexible Budget for Cost Center D

(at various volumes of production)

Normal Capacity—3,450 Standard Hours *John McDowell, Foreman*

Account	No.	40%	50%	60%	70%	80%	90%	100%	110%	120%	130%	140%
Foreman	41	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200
Assistant Foreman	42	....	.....	.....	.....	70	140	140	140	140	140	140
Helpers	43	250	250	250	250	300	300	300	300	300	350	350
Defective Work	44	60	100	200	250	300	400	500	650	700	750	800
Supplies	45	160	200	240	340	380	420	460	500	540	580	620
Tools	46	290	360	430	500	570	640	730	800	870	940	1,010
Overtime	47	....	.....	.....	.....	110	140	200	270	280	290	300
TOTAL		$960	$1,110	$1,320	$1,540	$1,930	$2,240	$2,530	$2,860	$3,030	$3,250	$3,420

Setting Overhead Budgets

For given amounts of production

BY REFERRING back to our underlying principles listed on page S35, you will note that there is emphasized the need of relating budgets of expenses to given amounts of production. (See Principle 2 and Principle 3). There is also stressed the importance of specific responsibility for definite overhead expenses. (See Principle 1.) Table IV and the description of it will point out the methods of establishing the above three principles.

By referring to Table IV it is seen that the items of direct overhead expense for Cost Center D are budgeted for the various volumes of production that may be experienced. By the use of this flexible budget sheet there is established for each volume of production a given allowance for expenses.

You will notice also in the upper right-hand corner of the sheet—*John McDowell, foreman.* He is the definite person who is held responsible for the items appearing on this budget sheet. No one else is responsible in any way, shape, or form. John McDowell just cannot pass the buck even if he wants to.

In the upper left-hand corner one finds 3,450 standard hours listed as the monthly normal capacity of this foreman's cost center or production section. Those hours are not clock hours but measured productive hours representing a given amount of tapping properly performed. In the column headed 100 per cent is the budget allowed for those 3,450 hours of a given amount of tapping. Likewise, other capacity columns are shown with the budget allowance for each capacity.

You now see how closely *the overheads of this section are definitely linked with a concrete measured amount of production and under a definitely named individual responsibility.*

Managerial Foremanship

With budgeting, each supervisor operates "his own business"

FROM the brief description of the above flexible budget and the responsibility it places upon the foreman one sees that a new type of foremanship is in the making. This new type of foreman is a manager-foreman in every sense of the word. And, if the flexible budget system is properly established, this foreman will operate his section just as if it were his own little individual business. In order to make this feeling of proprietorship effective, one must set up the figures in such a manner that the results of each period's performance will point out definitely whether or not this foreman and his section are doing better or worse than the budget (i.e., standard) by which they are measured.

As we shall see later on, each foreman will have his own monthly variance report which, as Ralph E. Case has so effectively pointed out, "is the equivalent for the section, to what the Profit and Loss Statement is for the company as a whole."

Foremen were heretofore con-

cerned solely with the building of men, machines, and materials. They had no definite responsibility for the control of the money value of these items. With the development of the flexible budget, however, the picture quickly changes. Everything the foreman does is interpreted against a known predetermined standard or budget. And it is this feature that makes a manager of him with full responsibility for his department. If managership means anything, it surely means controlling, guiding, and directing activities *within the confines of monetary limitations.* One can do most anything if there are no purse strings to be considered. Obviously, then, standard costs and flexible budgets constitute the basis for the managerial foremanship that is in the making.

Flexible Budgets for Executives

Same principles, different expenses

THE FLEXIBLE budget that has just been considered is obviously for a foreman. In studying it two important conditions should be clearly understood.

1. The budget at 100 per cent is the one and only one used for costing the product passing through this cost center. It is the standard cost that is always used regardless of what actual performance or volume of production takes place.

2. All other budgets are for control purposes only and should not be confused with the 100 per cent costing budget.

With these two facts held in mind, the next step is to consider flexible budgets for the higher supervisors such as superintendents, chief engineers, and the like.

The same principles are followed as in the setting of flexible budgets for foremen. The only difference is that a different list of overhead accounts comes under the direct responsibility of these higher supervisors.

To illustrate, let us look at Table V. This table shows the accounts for which the superintendent is held responsible. Only the amounts at 100 per cent normal or standard capacity are shown. Other budgets for different percentages of capacity will be worked out as was done for the foreman's budget (see Table IV).

Covering the seven operating departments, there are 28,000 standard productive hours of work for the month. Dividing this amount into $7,195 gives 26c. per standard hour worked as the standard cost for the prorated overheads.

Just as was pointed out regarding the foreman, the superintendent operates the fifteen accounts listed in the table as if they were his own business expenses. At any given volume of production he is allowed a certain budget covering these fifteen items. It is up to him to live within these budget allowances and if possible to beat them.

What is true of the superintendent's budget is likewise applicable to the head of the engineering department. He has a budget of expenses for the different volumes, and these expenses constitute a definite limit as to what he can spend.

TABLE V

Superintendent's Budget at 100% Normal Capacity

	Code	
Superintendent's Salary	101	$450
Assistant Superintendent's Salary	102	300
Engineering	103	1,100
Factory Accounting	104	300
Inspection	105	700
Heat, Power, and Light	106	700
Storeroom	107	100
Receiving Department	108	350
Shipping Department	109	450
Toolroom	110	400
Watchmen	111	80
Repairs and Maintenance	112	600
Insurance and Taxes	113	215
Depreciation of Buildings	114	666
Depreciation of Machinery	115	784
Total		$7,195

Fixed, Semi-Variable, Variable Expenses

Which are which?

NOT ALL overheads move up and down in direct ratio with the volume of production. Some items like rent, taxes, and depreciation are constant regardless of the amount of production. In contrast, certain other items like supplies and power tend to follow the production line rather closely. Still others tend to bend with production but not completely. In this last group of expenses are found such items as inspection, indirect labor, crane expense, factory accounting, and the like. These are known as semi-variable expenses, and may be worked out as are the items for "tools" or "assistant foreman" in Table IV.

The above condition is the basis for having flexible budgets—i.e., budgets set up for the various volumes of production.

Through the use of standard costs the difference between the actual happening and the standard is the variance, which is analyzed in detail both as to the amount and as to the cause. Likewise, differences between the budget and the performance are similarly analyzed.

Setting Standards for Overhead Expenses

Seven principles to observe

THE FOLLOWING principles should be observed by the management in setting the standards for overhead expenses:

Principle No. 1. Setting standards for overhead expenses is a scientific procedure. Therefore only trained and experienced engineers and accountants who employ objective measurements should be engaged in setting these standards. The plant superintendent, the rate setter, the foreman, and the plant accountant can readily carry on the control program once it is installed; but it requires experienced engineers to do the initial work and *train the plant personnel to the proper methods.*

Principle No. 2. An analysis of every expense is made. Not one solitary overhead item can be left out. Complete control is necessary. The installing engineer relates every expense item to volume. Materials handling, police duties, janitor service, inspection, oiling, set-up costs, storeroom expense, vacation expense —all are representative activities capable of such treatment.

Principle No. 3. In setting up flexible budgets, one and only one person is made responsible for a given group of accounts. To split an item for control purposes is to make for dual responsibility—which really means no responsibility.

Principle No. 4. The shop man—the foreman or the superintendent —brings to the installing engineer the experience of each expense item as it works in the plant. A budget made up by the engineer without the close tie-in of the shop would be little more than a paper budget.

Principle No. 5. The installing engineer in setting standards must draw heavily on his experience in other departments and in other similar industries. Only by a wealth of knowledge gained from setting many standard flexible budget can difficulties and mistakes be avoided.

Principle No. 6. Where the overhead expense item is a purchased one such as sometimes occurs with power and light, trucking service, steam, etc., it is wise to inquire from the seller as to the standard practice or standard performance to be expected, so that the greatest value may be obtained from the purchase and so that fair standards for overhead expenses may be set.

Principle No. 7. In a few rare cases it may be impossible to set scientific standards at the start of your flexible budget work. In such instances arbitrary amounts are established until trial and study—and study and trial—have given the engineer a sound basis for the amount that should be set.

Variances from Standard Budgets

Due to volume; due to inefficiency

VARIANCES *measure what is performed against what should have been performed.* And once you have such information for every activity in your plant and further have a definite person made responsible, then you are in a fair way properly and adequately to control your manufacturing expenses.

Inasmuch as standard costs have established a normal capacity, then capacities other than a normal capacity show a variance due to the volume influence. Charles C. James

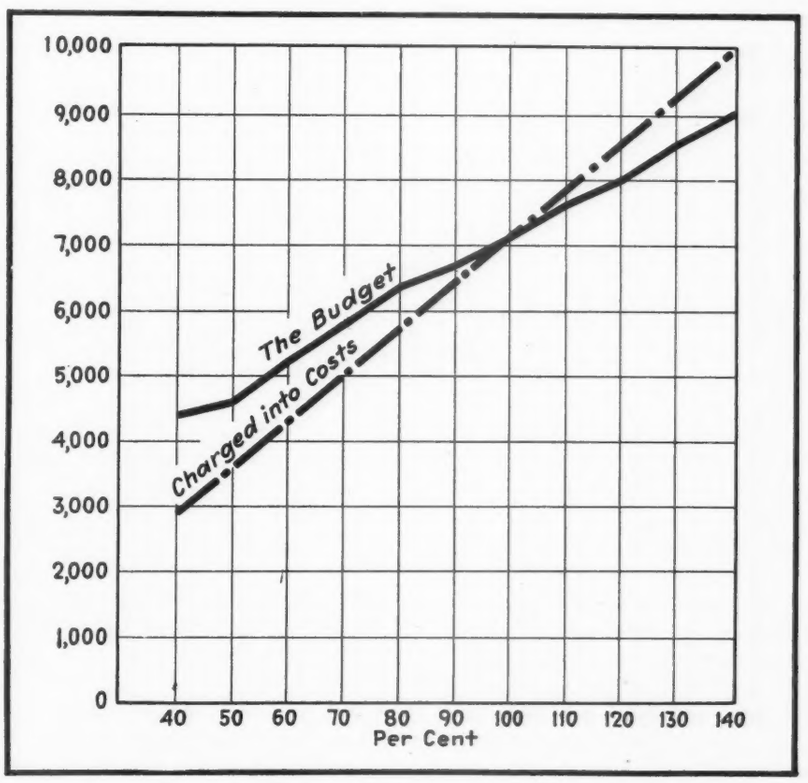

Figure 3. When volume is low, much of the fixed overhead expense fails to get costed into production

has very aptly called this variance from standard the *volume variance.*

Also, inasmuch as standard costs set a standard budget for every volume, then the difference between a budget for a given volume and what is actually expended at that volume is another important variance. It measures the efficiency of intra-plant performance. This variance has been termed the *controllable variance.*

A clear-cut distinction must be made between those variances from the standard cost that are due to differences in volume at which the plant produces, and those variances that occur because of the high or low efficiency with which production is carried on regardless of the volume.

The distinction is basic in securing sound management.

Under old *actual cost* methods which are misleading and inaccurate, the difference between costs due to volume and those due to inefficiency cannot be measured. *Standard costs,* on the contrary, clearly set forth these two highly different variances.

For industrial managers not to be able to determine the difference between costs due to fluctuating volumes and those due to the efficiency or inefficiency of operations, leads to a confusion that makes for false interpretation of all cost data. Practically all actual cost systems are worse than useless because of their inability to set forth this basic difference in costs.

Volume Variance

Favorable or unfavorable, it must be analyzed

OVERHEAD expense tends to vary with the volume of production. Not, however, in the same ratio. Certain overhead expenses, as mentioned before, continue at the same amounts regardless of production. Such items as depreciation, insurance, superintendent's salary, taxes, and the like are fixed, and therefore do not vary in amount, regardless of whether production is at 40 per cent of capacity or 140 per cent. By using the same standard cost rate for work performed, regardless of the volume produced, much of this fixed overhead expense fails to get charged into production when volume of production is slack.

Conversely, more overhead is costed into production than is necessary when production runs above normal. Figure 3 will tend to make this condition clear.

If production were at 40 per cent of the normal capacity, then the standard cost rate (always the same) would fail to absorb all the expenses. It would fail to do so because not enough production had passed through the plant. Had production gone beyond normal capacity—say to 120 per cent—then the variance between budget and amount costed would be very favorable as there is more charged into production at the standard rate than is necessary to cover the budget.

By closely studying the graph in Figure 3, there is obtained the meaning or definition of *volume variance.* It is *the difference between the budget for a given volume and the amount of cost that has been charged into production at the standard rate.*

Figures help to make this clear. Assume that production was at 60 per cent of normal capacity. At this volume the budget set for the needed overhead expense was $5,250. (See Figure 3.) The amount charged into costs at this volume, however, was only $4,340. The difference, $910, failed to be absorbed. This is the unfavorable volume variance—the extra amount of overhead expense due to the fact that production was 40 per cent off normal capacity.

Now take the opposite condition and assume that production was at 110 per cent of normal capacity. At this volume the budget reads $7,600 and the amount charged into costs $7,900. (Again see Figure 3.) Thus there has been costed $300 more than was needed to cover the budget—an amount definitely ascribable to the fact that operations were beyond the normal.

Management in this company is interested in a further analysis of volume variance. It is not enough for them just to find that for a given month there happened to be a favorable volume variance.

Three distinct factors are considered in analyzing volume variance.

A favorable volume variance in this plant may be due to the spring rush of business that directly precedes the automobile season. Again, the sales department may have beaten its sales quota and turned in a volume better than was anticipated. Perhaps, as a third factor, the economic cycle has come up faster than was projected, thus making for a more encouraging volume. Each of these factors is fully analyzed in gaining the proper interpretation of a favorable volume variance. Similarly, a complete analysis is made when the variance is unfavorable.

Controllable Variance

Every expense item under definite personal control

CONTROLLABLE variance may well be defined as *the difference between the budgeted expenses established for a specific volume of production and the actual expenses incurred in producing that volume.*

Previous mention has been made of the necessity of having different budgets made out for the different volumes of production at which the plant or cost center may operate. Further, it has been pointed out that a comparison of the amount of overhead expense costed into production at the standard rate, contrasted with the overhead expense budgeted for that production, showed the volume variance.

TABLE VI
Controllable Overhead Expense
(Report to Foreman)

Cost Center *F* **Month of** *August* **Foreman** *Gridley*
Operating Rate of Capacity *118%*

Expense Item Name	Code	*Budget* Allowed	*Actual* Performance	*Better or worse than Budget (Worse in Italics)*
Foreman	21	$300	$300	.....
Asst. Foreman	22	175	175	.....
Misc. Wages	23	500	470	$30
Inspectors	24	500	536	*36*
Clerks	25	600	550	50
Helpers	26	1,190	1,086	104
Repairs	27	1,330	1,254	76
Defective Work	28	820	730	90
Materials Handling	29	2,180	2,042	138
Supplies	30	760	824	*64*
Overtime Bonus	31	850	898	*48*
TOTAL		$9,205	$8,865	$340

Now, then, if the actual overhead expense at any capacity is compared with the budget of overhead expense for that capacity, there are obtained variances that measure the performance of the plant managers in meeting their budgets. As direct overhead expense is definitely budgeted for cost centers and prorated expenses are budgeted for the superintendent, this means that the foremen of the cost centers and the superintendent of the plant are held responsible for all the operating department expenses that have been incurred.

Definite Control by Those Responsible

Thus we come to the very heart of standard costs and their flexible budgets in controlling expenses. *The ability to place before each manager in the plant, from foreman of each cost center to general manager, a group of overhead expenses for which each is made responsible and for which each is budgeted, gives a definite control of overhead expenses that the science of cost accounting has heretofore never accomplished.*

Make no mistake about it. No more are overhead expenses allowed to dangle around in thin air. Rather, they are now budgeted—i.e.,standards set—*for those specifically responsible for making savings.* Not one item of overhead expense can remain unbudgeted. Further, no budgeted overhead expense item can remain outside the responsibility of a definitely named manager or supervisor.

In brief, every overhead expense item is budgeted and placed under a definite personal control. Such procedure places overhead expense control under the same rigid measurement that standard-timed labor rates have established for direct labor.

One hard and fast principle must be followed in determining what items go into a budget for a specific foreman. It is this: Only those overhead expenses that are wholly within the cost center budgeted (direct expenses) can be placed under the responsibility of the foreman. No arbitrarily prorated items can go into any budget. Such items are left in the budget of the superintendent where no prorating is necessary. If, for instance, an inspector covers three cost centers, his salary is not prorated to the cost centers. Instead, his salary comes under the superintendent's budget where no prorating becomes necessary. Likewise, certain portions of other overhead expenses, such as shop accounting, police expense, and the like, cannot be broken down except by arbitrary rulings. *Very well—do not break them down, but put them into the general manager's or the superintendent's overhead budget.*

No Arbitrary Split-Up of Expenses

By following this principle, never is the accounting department embarrassed by having to justify an arbitrary splitting of expenses and budgets among several cost centers.

This rule, however, does not prevent the prorating of certain expenses for costing purposes. It is merely intended to avoid charging the foreman with expenses, such as rent, that he does not control. In short, all prorated items must be broken down to cost centers in order to get the standard cost rate for the cost center.

To make the meaning of controllable variance clear, it might be helpful to illustrate by specific figures. Referring again to Figure 3, let us take as experienced a production of 70 per cent of volume. The budget for this volume is seen to be $5,800. When the actual overhead figures for the month are collected, the results total only $5,715. Thus a *favorable controllable variance* of $85 is indicated.

But Volume Variance Is Unfavorable

It is interesting to note that there is an *unfavorable volume variance* at this volume of production of $750 (see Figure 3). How would the poor old "actual" cost accountant interpret the situation? He would simply say that unabsorbed burden was $665; and what it was due to, he'd leave in the laps of the gods.

Let us carry this matter of figures

a little further. Controllable variance must be broken down into its component parts so that the foreman or other supervisor can see where he has gone astray. Table VI is a report to a foreman for a given month.

The total controllable variance experience of this cost center for the month shows $340, found by comparing the monthly expense budget of $9,205 with the total actual expenses of $8,865. It is this $340 that represents definite savings in this cost center and it is the amount upon which key man bonuses are calculated, as we shall learn. The savings are identified with Cost Center F, and Stub Gridley and his assistant foreman are rewarded specifically for the savings they have made. The plan for paying key man bonuses is outlined later.

To show the amounts of controllable variance as presented in Table VI is not sufficient information for plant managers. These figures show the amount of the variance and the item in which the variance occurred. What to do about it, needs an immediate follow-up.

Table VII is a sheet arranged for the purpose of following up all unfavorable variances. Definite causes are listed and a report of progress is indicated.

The listing of the responsible person is an attractive feature. It gives a personal responsibility for wrong conditions and portrays the endeavor to make amends.

The importance of this plan of determining controllable variances must be driven home hard. The identification of controllable variances in the plant with supervisory responsibility constitutes a tremendous stride forward in redeeming overhead expenses from the class of illusive uncertainties to placing them under a rigid and definite control.

Let us now proceed to a discussion of a bonus plan that gives to the supervisory force rewards based upon the savings in expenses that their efforts have achieved.

Key Man Bonus

Based on net savings made by supervisors

ACTUAL overhead expenses incurred for a given volume of production in comparison with the budget of overhead expenses allowed for that volume give the basis for measuring savings and calculating the amount of key man bonus. In short, controllable variance is the basis of key man bonuses.

The bonus that is paid to the foreman, assistant foreman, or any other supervisor within the cost center is based upon the net savings which they have made for that cost center.

A sound method for the operation of the bonus is not to give it all in immediate cash payment but to pay part in cash and place the remainder in a fund. This fund acts as a reserve against which negative variances are charged during the year. After this period, if there is a credit balance in the fund, it is divided according to the individual creditors entitled to it.

A certain percentage of the sav-

TABLE VII

The Follow-Up Sheet—Unfavorable Variances

Month of *August* — Cost Center *F* — Foreman, *Gridley*

Fall-down Accounts Name	Code	Amount	Name of Responsible Person	Cause of Over Budget	What to Do	Report of Progress Sept. 3rd	Sept. 5th	Etc.
Inspectors	24	$36	Fred Stone	Slow checking	More efficient scheduling to prevent delays	New schedule drawn up	New schedule working	O.K.
Supplies	30	$64	Pete Wells	Over-pull of paint from storeroom	Cannot be prevented			
Overtime Bonus	31	$48	Tom Fry	Necessary to complete specific job	Better scheduling of rush orders	Check all rush order work	O.K.	O.K.

ings under controllable variance goes to the cost center supervisors; one-half is paid in cash the first pay day following the period in which savings were shown. The remaining half is turned into the fund as a reserve to which individual supervisors have rights.

By referring to Table VI we see the net savings for the month, or the controllable variance, is $340. Of this saving $68, or 20 per cent, goes to the supervisors considered as responsible for it. Automatically, $34 is paid to them in cash and $34 is placed in the reserve.

The method of sharing this bonus of $68 among the supervisors is on a point scale basis. Each supervisor is given a certain number of points based upon what is considered his respective value in making savings. In Cost Center F, for instance, but two men are involved in the savings —the foreman and the assistant foreman. The point distribution between those two is as follows:

Foreman	100 points
Assistant foreman .	60
Total points for cost center	160 points

Dividing the bonus of $68 by the 160 points gives a point valuation of 42½ cents. Thus the foreman receives a bonus of $42.50 and the assistant foreman $25.50. The foreman obtains $21.25 cash bonus and the assistant foreman $12.75, with like sums going to their credit in the bonus fund.

A separate bonus fund is established for the supervisors responsible for the prorated expenses, and it operates exactly on the same principle as that described for the cost center supervisors—i.e.,the foremen.

Some concerns hold that the head supervisors lend influences that make the cost centers more efficient, and that these supervisors should share in the cost center savings as well as in the prorated expense savings. If this is desired, a certain percentage of the cost center savings can be placed in the prorated fund in addition to the bonus coming from prorated savings.

The cardinal principle followed in this form of bonus is *that each supervisor's bonus is closely allied with the work and the expenses under his direct control and with the savings his control accomplishes.*

Such a key man bonus, then, is an excellent capstone to a standard cost and flexible budget system. If the supervisors beat their budgets, they are awarded bonuses accordingly; if they fail to meet them, their reserve funds are diminished.

Such a method is fundamentally sound because it rewards specifically those responsible for definite savings achieved.

❖

QUESTIONS AND ANSWERS

The following questions have come from the supervisory force of an industrial establishment whose method of controlling overhead expense is similar to the principles set forth in this paper

Question 1. How is set-up handled?

Answer: The average amount of set-up expense experienced in the past for the standard volume is established and divided by the total standard labor hours. This gives the standard rate per hour for set-up. This rate is added to and becomes a part of the standard cost rate. Variances both favorable and unfavorable are shown by comparing the actual set-up expense with the amount costed at the standard rate.

Question 2. How are large unforseen expenses treated?

Answer: A "budget allowance" is established to meet these necessary adjustments. The variance is shown as budget adjustment. Variance is thus kept away from bonus fund influence but still shows as a variance from standard.

Question 3. How often are the budgets for overhead expenses changed?

Answer: They should, if at all possible, not be changed in a shorter time sweep than one year. To change them oftener means a new set of budgets and quite often difficult adjustments in inventories.

Question 4. If a supervisor makes an admittedly out-of-line bonus ("lots of gravy"), should the budget forthwith be lowered?

Answer: No. The higher supervisors, the consultant engineer, and the plant accountant helped in establishing the budget. If error has occurred, it is better for the *esprit de corps* of the plant to let it alone until the end of the year. In contrast, if the budget is obviously set too high, give a budget allowance rather than penalize the supervisor.

Question 5. A supervisor has his workers turn out many more standard hours than expected. How can he be rewarded?

Answer: Take a certain percentage of the savings shown and place it to his credit in the bonus fund.

Question 6. How are vacation expenses handled?

Answer: Estimate the expected amount of vacation expense, prorate it on the basis of number of employees to cost centers. Then divide the amount prorated to cost centers by the standard hours of that cost center. This gets the expense into the cost rate. For budget purposes set it up as a prorated expense on a monthly basis.

Question 7. How are individual jobs costed?

Answer: By applying the standard cost rates of each costing center through which the job passes and for the allowed standard time in each of these centers. This information is shown on a route sheet.

Question 8. Do differences in volume show up in the cost of specific jobs?

Answer: Emphatically no! Costs of jobs are at the standard cost rate figures for normal or standard volume. Differences between the standard cost and the given volume show as volume variances.

Question 9. What cost figures are given to the sales department?

Answer: The standard costs of all jobs. In addition, the volume variance figures are given to the sales department so that the sales manager may see opportunity of stimulating sales of lines that are weak in volume.

Question 10. What is the position and nature of the work of the plant accountants under this plan of handling overhead expenses?

Answer: The question is very important. Once you understand clearly the operation of the controllable variance you realize there is a very effective tool of control over the foreman, superintendent, and other key men. This control points out whether or not the key men are effectively using the expenses that are under their jurisdiction. Obviously, the plant accountant, with the plant engineer, must work very closely with the key men in the shop in order to set up a satisfactory budget. If there does not exist the finest spirit of cooperation between the plant accountant and the key men, the set-up of a satisfactory budget is well-nigh impossible. Standard costs and flexible budgets thus demand that shop management and shop accounting lock arms and move forward together.

Question 11. What effect does a standard cost and flexible budget plan have on the plant accounting reports?

Answer: The effect is fundamental. Standard costs and flexible budgets call for better accounting reporting than most of us have been used to. The accounting reports must, first and foremost, meet the specific needs of the shop. They must be simple, to the point, and not tied up with a lot of technical terms that are meaningless to shop men. Furthermore, many key men may wish their variances put up in the form of graphs or charts. Others will wish to have them typed in tabular form. Still others may demand that the accountant sit down with them and explain reports in detail. Fine. What a splendid opportunity for really valuable cooperation. The accountant deals with realities and men instead of with figures on pieces of paper.

PRODUCTION CONTROL

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CHAPTER ONE

Introduction

FOR a good many companies the problem of production control has been a hectic alternation of rush to get out an order the customers wanted day before yesterday, and of idleness and marking time until the next order arrived. If the predictions of one of our leading commercial agencies are correct, and the expected improvement of business materializes, companies that have allowed their production control methods to get rusty when there was little apparent use for them, are likely presently to be caught short. It is a good time to do some overhauling.

Also, production control may well be said to have passed through the period when a delight in new gadgets and elaborate systems often blinded the engineer and manager to practical requirements. The first stage in production control was that in which little or no planning was done in advance; the order was simply tossed to the foreman with a few vague instructions as to when it was wanted, and a horde of stockchasers were relied upon to get deliveries. As the factory got further behind, more chasers were hired. But since most or all of the orders had to pass through certain bottlenecks in the factory, and since management was often quite unconscious of the existence of these bottlenecks, the net achievement of the extra chasers was to interrupt jobs and slow down work still further. This system is still in common use, although the chasers have not been busy of late.

The discovery that one could estimate fairly closely in advance how long it would take to perform an operation was at first ridiculed as both impracticable and too costly in detail to bother with. But as our knowledge of standard time analysis has increased, an almost mathematical basis for effective production control has been developed.

With the discovery that it was possible to control production has also come a realization that it is economical to do so. Usually the first stage in a change is that the new standards and systems are not sufficiently reliable to be operated alone, so that for a time the cost is greater and the results perhaps less than before. This stage may result in throwing the new system out; if it does not, and the plan is well designed, the company eventually gets a control at the source which saves all sorts of waste motion.

CHAPTER TWO

Stock-Limit Control

PRODUCTION control plans may be divided into two main types. First is the stock-limit control plan, in which the material or its component parts are made up from time to time in lots of a sufficient quantity to balance the cost of setting up a machine for the run, and the cost and risk of carrying the part in stock. This system has the advantage of eliminating much of the hasty and costly production necessary when all orders must be made up after receipt; the stock acts as a cushion to absorb the minor irregularities of customer demand and to permit orderly production.

Limited, but Not Obsolete

On the other hand it has two serious drawbacks. It costs money to carry stock. Capital is tied up, and the volume of business the company can handle is reduced; there are direct costs for handling, storage, interest, insurance, taxes, and other charges; there is a serious risk that some part of the stock may become obsolete and have to be scrapped. In the second place, where the stock-limit plan is relied upon exclusively for control, where all or most orders originate when the balance of the items on hand reaches the minimum stock limit, orders are likely to be released to the factory in an irregular and jerky fashion.

Over a period of time, of course, there will with any control system be only as much work released as there are sales calls for the product of the department. But where it is possible to anticipate the call for a particular product, where the volume of the product is sufficient to allow continuous operation for considerable periods, the foreman can do much better planning where he works to a daily quota than where large orders descend upon him at irregular and more or less accidental intervals. For example, it may happen that two or three parts, all manufactured at the same machine, may reach a minimum at nearly the same moment, and then for weeks there may be no more work coming through for this machine.

Because of these defects, the large inventory required, and the irregularity of the flow of shop orders, the stock-limit plan of production control is regarded as obsolete by many manufacturers. It is *not* obsolete, however, and probably never will be, for certain industries and situations.

Lot Size Influences

The principles for determining economic lot size, for setting the "maximums" in stock-limit control, have been known for many years, although these formulas are even yet in everyday use in only a comparatively small number of concerns. This is not the place for a detailed demonstration of the lot size formula, but in general it rests on the familiar principle of a balance between the initial costs for machine and clerical preparation time, and the costs of carrying the order in stock after it is produced. The set-up cost per unit of product is high for small lots, but tends to decrease rapidly per unit as the size of the lot increases. On the other hand, interest, depreciation, storage costs, and other "carrying charges" increase more or less proportionately and at a more or less constant rate as the lot size increases. A point of balance and of lowest cost may be found, either graphically or by formula.

So Do Set-up Costs

Now, unless there is enough volume to keep a given department or process busy constantly, either the year round or for seasons of two or three months, it follows that lot production is in such cases the most economical method of production control, even considering the cost of carrying the inventory. The larger the set-up costs, the stronger the case for stock-limit control of an item produced in insufficient volume for day in, day out operation. Set-up costs are likely to be high in parts production, often involving such operations as setting presses and machine tools, charging furnaces, vats, or ovens, and the like. Assembly processes, with a larger proportion of hand work, often involve slight set-up, and it is a common situation to find stock-limit control for parts, combined with final assembly to customer's order or to quota.

In any case, the question of whether or not it is economical to produce to stock limits is capable of fairly definite analysis on the basis of ascertainable facts. It is not al-

PRODUCTION CONTROL RECORD
NAME OF PART Coil Spring
SOURCE

Cost per unit ----- 0.15
Quant. for process---500
Deliver to dept. ----- F

PART NO. 441-S

Used on model No.	441	941	991
No. used per model	80	80	90

Order No.	Quantity ordered	Total ordered	PURCHASE RELEASE Month	Quant.	Total	PURCHASE DELIVERY Date	Quant.	Cumulative total	DELIVERIES DEPT. F Date	Quant. good	Quant. scrap	Cum. total good	DELIVERIES DEPT. ------ Date	Quant. good	Quant. scrap	Cum. total good	ETC.	Total scrap (re-order)
126	30,000	30,000	April	5,000	5,000	4/8	4,000	4,000	4/15	898	2	898	4/25	898	3	895		3
			May	5,000	10,000	4/22	1,100	5,100	4/22	2,850		3,748	4/30	2,849	1	3,744		4
			June	5,000	15,000	5/7	4,500	9,600	4/29	1,215	10	4,963						

Figure 1. Provides for a continuous balance of production against orders ahead

ways possible to set precise values on such quantities as total set-up and clerical costs, or probable depreciation or fluctuations in market price of materials, but even an approximate estimate of these factors will give a better solution than going on the basis of habit or opinion without analysis.

And Ordering for Stock

The second objection to stock-limit control of production—the jerkiness of the shop schedule that results—may be alleviated by a modified use of stock limits. In many companies, the superintendent goes over the stock records at regular intervals and, by placing orders for stocks that are approaching exhaustion but are not yet at the low limit, is able to regularize the manufacturing schedule.

One company has developed an ingenious method of reducing the executive attention required to even out schedules with stock-limit operation. The stock record card has a place for three quantity controls—a maximum, an ordering point, and an "urgent" point. The stockkeeper issues a production order in regular course when the balance on hand reaches the ordering point.

Shop orders for these items are issued on a form of distinctive color, and foremen are instructed to give the right of way against these orders to customers' or rush orders. If, however, subsequent withdrawals of an item pull the balance down to the urgent point before the new order is received, the stockkeeper notifies the superintendent, and the shop order for the item is at once transferred from the "backlog" to the preferred class, being followed up to make sure that it is not delayed and taking right of way equally with customers' orders.

CHAPTER THREE

Quota Control

STOCK-LIMIT control might be used in making a product such as an automobile motor. But in general any such product always requires a balanced ratio of parts—so many pistons, wrist pins, timing gears, and so on. If the number of motors to be manufactured is known, the parts requirements may be automatically and simply extended and posted to a requirements record such as that shown in Figure 1. If now the process times per part and the available machine capacities are known, a uniform daily delivery schedule may be set up for each department concerned in making the part. Furthermore, the receipt of new orders for the part will merely have the effect of extending the life of this schedule, or of increasing it if more capacity is available.

The capacity of a machine is a fairly definite thing. No amount of coaxing or threats, no proffer of bonus will hurry it. The capacity of a man is somewhat more flexible, but even here the attempt to crowd production beyond a certain point, except for short periods, results in an increase of errors and spoilage and an eventual reaction.

Consequently the task of scheduling products, such as the parts of the automobile engine mentioned, becomes again a problem in simple arithmetic. Knowing the capacity at each process, the days required for delivery can be foretold closely. The foreman knows how much work is ahead of him; the management knows what delivery it can count on.

Three Ways to Turn

If this rate is insufficient to meet promises to customers, or the requirements of the sales department, three possible courses of action are indicated. The management may order new machines and put additional men to work; it may turn to outside suppliers for the parts it cannot produce; or it may instruct its sales department to take the pressure off the item or the whole line until the factory can catch up. Assuming that each department is really at capacity, it is a waste of time to expect more, and efforts are concentrated on keeping the path clear for the business on the schedules.

It is perfectly possible, and desirable in many cases, to supplement the daily quota by stock-limit regulation. The form shown in Figure 2 provides for a continuous balance of production against orders ahead; it may be desirable to set high and low limits within which this balance must be kept. If it reaches either, the production department increases or decreases the daily quota by an amount calculated to restore the balance of production.

When Making One Product

The simplest type of production control is met where a single product, such as cement, is manufactured. Here the entire producing line will be fully, or as nearly as possible, balanced, and a single order will suffice for all departments. After the average daily demand for the article has been determined, a weekly or monthly schedule of required output per day will enable every foreman to plan the crews he will need, will serve as notice to the purchasing department of the deliveries of raw materials for which it must provide, and will enable the treasurer to estimate the provision he must make for payrolls and material bills.

First modification of this simple type of control is that entailed by a change from one product to another. Here it is usually necessary to allow time for a change-over from the old to the new product, and it is usually advisable to accumulate a bank of work in process between one department and the next, so that minor interruptions in any department will not be felt in the later processes.

To meet this situation, the break in the process is timed to progress in wave fashion through the departments. Department 1 is timed to complete its quota of product *A* on Monday, has Tuesday free for set-up, and is scheduled to produce its quota of product *B* on Wednesday. Department 2 may be scheduled to produce

DATE	APR. 25		26		27		28		29		May 1	
DEPT. NO.	MODEL	QUOTA	MODEL	QUOTA	MODEL	MODEL	QUOTA	MODEL	MODEL	QUOTA	MODEL	QUOTA
107	B	100	Set-up		C	100	C	100	C	100	C	100
115	B	100	B	100	B	100	Set-up		C	100	C	100
116	A	100	Set-up		B	100	B	100	B	100	Set-up	

Figure 2. A modification of quota control occasioned by a change from one product to another

its last day's quota of product *A* on Thursday. On Friday it receives Wednesday's and Thursday's production from department 1, and thereafter receives a daily delivery equal to its own quota, maintaining one day's bank constantly, except for the fluctuations in rate, which it is the purpose of the bank to absorb.

Schedule Out Idle Time

Each succeeding department will be scheduled on the same principle in relation to its predecessor. At the end of the run a new lot will move through the departments with approximately the same time intervals as the last, so that there need be no idle time so long as there is work ahead.

This principle was employed to advantage in a piano factory which manufactures uprights and grands in various models. As the season progressed the sales department was able to give information as to the quantities of the various kinds likely to be required, and these were put through in large runs, first the models of one type, then of the other.

At each change-over from one type to another, a certain amount of rearrangement of equipment was required, since the production line that was balanced for uprights was not balanced for grands. Some men had to be shifted to new machines. Once set up, however, every department produced its daily quota. Models that did not disturb the general balance of the line followed one another with just a sufficient interval for the change of patterns and the supplying of a walnut instead of a mahogany veneer, for example, at the proper assembly points.

Evidently, in any control of this type, raw material must come in at the proper place and time, on a schedule synchronized with the operating schedule and constructed on the same principles.

CHAPTER FOUR

The Block System

MEN'S tailoring offers a good example of another modification of this type of control. The sale of suits to retailers customarily begins several months in advance of the season of consumer demand. This gives a chance to collect the greatest diversity of combinations of goods, patterns, suit models, styles, and sizes, so that as far as possible suits cut from the same pattern of woolens may go out to the shop together.

A suit is like an automobile motor in that there is a general balance of parts and processes. Indeed it is an even better case for balanced flow production, for, while the automobile engine may have from 6 to 16 cylinders, about the only major variation in suits is in the omission or use of patch pockets, full linings, double rows of buttons, and like details. Consequently, with minor changes in a process here and there, a suit will flow through cutting and assembly or tailoring processes to final pressing and inspection, with very little change in the balance of time requirements at each point. Furthermore, since most of the work is done by hand or with sewing machines which require little change of set-up to switch from one order to the next, orders can follow each other in a practically steady stream.

There remain in men's tailoring only two important production problems. One is to see that instructions, time tickets, and the necessary supplies or "findings" accompany each lot. This problem is solved by making out a standard instruction card and book of time tickets for each order, and putting them togéther with a supply of findings drawn from stock, with each order as it leaves the cutters.

The other problem is to see that the various parts of a coat, the sleeves and back, for instance, come together at the same times and places for the various stages of assembly. To meet this need, the "blǫck system" has been developed and has found an application in many lines quite different from men's suits.

Blocks Are Time Periods

The block system is merely an application of the method of change-over of models, illustrated in Figure 2. A "block" is usually, in the tailoring trade, an interval of a half-day. In the order filling department of a large manufacturer of surgical supplies, the week is divided into 40 (or less, depending upon the amount of business) blocks of one hour each. In order filling in the large mail order houses, blocks are 15 minutes in length.

Whatever the length of the block, enough orders are put together to fill it approximately. For example, the plant capacity might be 500 suits per half day. Block No. 1, to start Monday morning, would then contain orders of various quantities to an aggregate of 500 suits.

The weekly schedule would show that block No. 1 was to leave Department 1 by Monday noon. It should be delivered from Department 2 to Department 3 by Monday night, and so on to each department according to the schedule. Longer intervals might be allowed certain departments subject to interruption, or for delays for transportation, or similar causes.

As each department receives a new block or lot of suits, it signs for it. The foreman's clerk crosses off each suit or order as it is finished, until every order on the block is crossed off. Then the lot in the block is sent to the next department and signed for in like manner. As a block is delivered from one department to the next, the block number is reported to the main office as cleared. No block is cleared for any department until it is complete. No block is cleared until every preceding block has been cleaned up. A report of blocks behind schedule goes to the factory manager each day.

As may be imagined, the plan puts a heavy pressure on every department to clean up each block as it comes. A single suit, put aside because it is "fussy" and the men leave it till the last, may hold up two or three blocks and bring every department in the plant down on the neck of the responsible foreman. In unavoidable delay, the schedule clerk has authority to transfer the delayed order to a later block or to take it out of the production line altogether. If there were too many such interruptions, the system would break down; it is adapted only to line production in which there is a relatively constant and dependable balance of producing capacity.

CHAPTER FIVE

Production Standards

THE SUCCESS of all plans for alloting definite daily quotas to operating departments rests on the dependability of the standard times on which these quotas are based. Many firms continue to get along with looser and less effective systems of production control, because they boggle at the expense of making the time studies, process analyses, and other steps of standardization upon which dependable estimates of production time requirements must be based.

With some types of work it is perhaps impractical to establish standard times, as, for instance, where the factory handles special work and the job is rarely if ever repeated. Even here, however, the use of elementary time formulas is more and more making it possible to predict times within close tolerances and to permit a workable schedule, in any industry in which the general order and flow of operations remains the same, and in many cases lacking a constant order of processes.

In some industries, as in the molding of structural terra cotta facings, it may not be possible to set a rate for each job, since practically every ornamental block is individually designed. Here, however, in one plant a classification of job according to degree of difficulty made it possible to estimate time requirements with approximate accuracy. Even toolmaking, usually thought of as the last work in irregularity of performance, is being estimated within reasonably close limits.

Week ending — OPERATING SCHEDULE — Dept. A

June 9		June 16		June 23		June 30	
Order No.	Quantity	Order No.	Quantity	Order No.	Quantity	Order No.	Quantity
416	100	533	50	533	50	715	100
533	50	607	300	619	10	661	200
534	200			660	100		
535	35			661	200		

Figure 3. To combine operating schedule with operating budget, the expected daily output is set down week by week

The establishment of standard times is somewhat like a capital investment, as would be the production of standard drawings and specifications for materials and parts in a shop that had heretofore worked only from samples. The job will cost a certain amount of money, depending upon the number of studies to be made and the extent of changes likely to be required. It has been repeatedly demonstrated, however, that if the work of process analysis and standardization is thoroughly done, it is likely to pay its way or even show considerable profits from its by-products. Such studies, if thoroughly done by competent engineers, have a way of revealing unsuspected wastes and inefficiencies, many of which can be remedied with surprisingly small expense.

There are also other byproducts from careful and thorough standardization of production methods and times. If these are accurate, it is evidently possible to predict not only the time required for an operation but what it will cost. Standard or estimated cost systems are steadily growing in favor and seem destined within a few years to displace the older cost systems almost completely. Not only are they more accurate, but, by saving the endless recording and re-recording of costs on different lots of the same product, and by limiting attentions to variations from standard, these new cost methods actually cost less to operate than the old historical cost systems.

Schedule Output, Budget Costs

Evidently, if process times, costs, and material requirements are known, it should be possible not only to schedule output, but to schedule costs. It is becoming the practice, therefore, in the more modern plants, to combine the operating schedule with the operating budget. For each department, the expected daily output is set out, week by week, on much the same principle as that illustrated in Figure 3. The schedule may call for daily delivery of one model or part, or of several models running simultaneously in the department, the only requirement being that the total required time shall at no point

exceed the capacity of the department to deliver according to schedule.

Parallel to this schedule, there is constructed a budget of the allowed or standard cost of operating the department. Labor piece rates or other wage requirements will be extended on the basis of the unit times required for the operations scheduled. Materials, supplies, and "indirect" expenses, together with constant expenses such as depreciation, fixed salaries, rent, and the like are added to give the total standard cost allowed the department.

Considerable economy in clerical expense may be realized when all the elements in production control—schedule, cost system, and financial budget—are thus integrated into one system. One large factory, employing several thousand people, was able to extend its shop schedules, department budgets and purchase releases with a force of only four people by such an integration.

CHAPTER SIX

Decentralized Dispatching

THE USE of the quota or time budget plan, in all its many variations, makes possible another economy, as well as a corresponding improvement in schedules.

It should be possible to operate a "balance of time," somewhat similar in principle to a "balance of stores." This is, in fact, done when a department's or a machine's capacity is scheduled ahead against orders—for example, up to June 10 on order 716, from June 10 to July 1 on order 8815, and so on. This principle is used graphically in the Gantt chart, to which later reference will be made.

Now to the extent that these schedules are accurate, meeting them is wholly within the power of the foreman. Unexpected breakdowns may cause him to fall down on his deliveries, but in normal times the schedules will contain a small allowance for such delays, and in rush times, with capacity stretched to its utmost—well, we rely upon a similar application of budgeted maintenance to avoid breakdowns. The schedule will not prevent breakdowns, but it *will* pick up the thread in the shortest possible time after service has been restored.

Central Department Controls

With a good schedule there is no use keeping an army of stockchasers to ask the foreman if he can't get nine hours of work out of a machine in eight hours. The whole control of the sequence of orders is in the hands of a single central department, which is in a position to keep itself continuously informed of changes in customers' needs, plans of the sales department, and similar urgencies whose direct impact is so demoralizing to shop production. The central department is responsible to the general manager for securing the best practical balance between sales and manufacturing necessities.

This central department in turn knows how much load a foreman can carry in his department. To check this, when the foreman receives his periodical schedule of orders ahead, he is required either to accept the quota and take the responsibility for meeting it, or to raise promptly any difficulties or reasons why he thinks the schedule should be modified.

There is room for a considerable degree of latitude as to the amount of detail to which the central department shall go. It may extend every operation element, carrying, by means of a graphical or other record, a schedule of the work ahead of each production center. Or it may schedule only the sticking points, the bottlenecks of production at which, for the moment, a delay is likely, leaving it to the foreman to make his own arrangements for the remainder of the processes. Or it may estimate only the total hours required by the job as a whole in the department, relying upon the averaging effect of a succession of orders to prevent bottlenecks.

Obviously, a general schedule of this nature will break down if either the central production control department, or the foreman, or both, exceed a certain degree of inaccuracy in their estimates of capacity. This system is therefore not applicable in shops that have not attained a certain standard of dependability and completeness in their records of unit operating times.

Foreman Must Meet Schedule

Once the foreman has accepted the schedule, he is left to carry it out in his own way. If for any reason he foresees that he is not going to be able to meet an accepted date, it is his responsibility at the earliest possible moment to go to the management for help, so that the full strength of the organization, from president down, may be mobilized to remove the difficulty if it is of enough importance.

The effect of this decentralization is to cut out an immense amount of red tape which used to be a feature of some of the more elaborate systems. Decisions as to which job a man shall do next are no longer made in a remote office and communicated

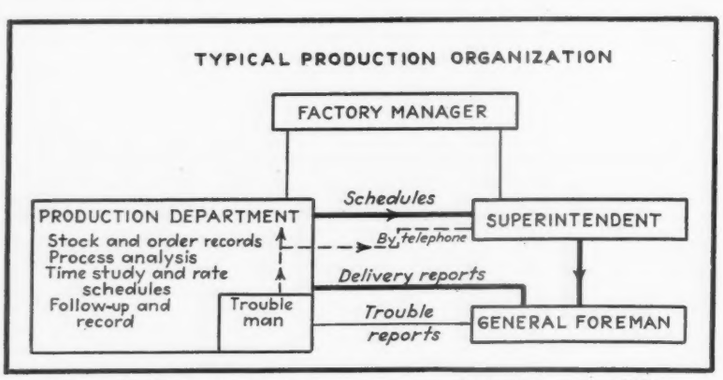


Figure 4. Typical organization set-up in which the responsibility for production is well-defined

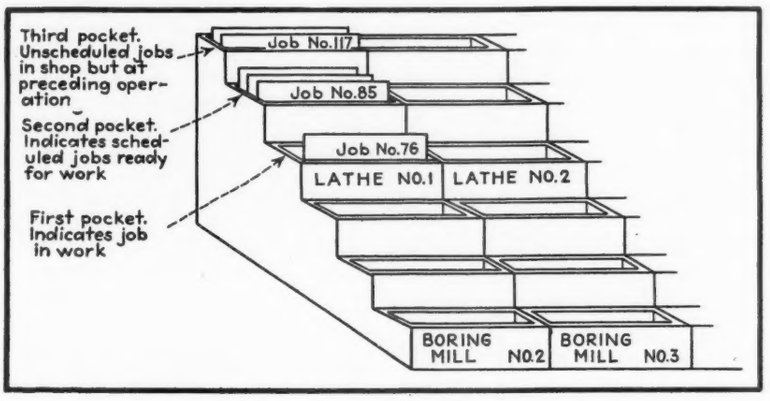

Third pocket. Unscheduled jobs in shop but at preceding operation
Second pocket. Indicates scheduled jobs ready for work
First pocket. Indicates job in work
Job No.117
Job No.85
Job No.76
LATHE NO.1
LATHE NO.2
BORING MILL NO.2
BORING MILL NO.3

Figure 5. A planning board keeps scheduling from getting too complex

to the man by pneumatic tube or telautograph, although these means of communication may be useful for other purposes. The foreman has all the essential facts with which to run his department; he has the backing of the management in case he gets into difficulties. He assumes the full responsibility for running his department and is judged by the results, both in terms of meeting schedules and (when the department budget plan is in use) of meeting or bettering the allowed department costs. Figure 4 is a diagram showing a typical organization of this type.

Foreman on His Own

Within his own department, the foreman may use whatever method of detailed scheduling is most suitable. If the situation is simple, he will very likely carry it in his head. If there are too many details to look after to make this safe, he may use a planning board of Taylor type (see Figure 5) or one of the various visible indexes or graphic charts to make sure that every order is started on time.

He or his assistant in charge of production receives a periodical release, usually weekly or monthly, from the central planning office. This release may be a list of orders to be filled day by day. Or it may call for a daily delivery of so many units of one or more parts. The principle on which deliveries are assigned will be somewhat like that explained for the assignment of blocks under the block plan.

On receipt of the order, the department proceeds to check schedules already accepted to see whether it will be able to meet the required delivery date. Assuming that the order can be accepted, the department will then put the order into a daily "starting tickler," or assign it a place on the planning board, or otherwise schedule it so that it will receive attention at the time required.

Materials may be arranged for, if that is the responsibility of the department. In many cases material is delivered from stores by the purchasing department or the preceding department according to a schedule designed to dovetail with that of the succeeding departments. The foreman or his clerical assistant will check the receipt of the material and will get after items that are not delivered according to schedule, but will not be otherwise responsible. Tools, drawings, gages, and other accessories will be handled much as are materials. The department may deliver the product to the next department when finished, taking a receipt and reporting to the central planning office, or let a general material-moving service handle it.

CHAPTER SEVEN

The Tools of Planning

AT THIS point, having set up a picture of the objective and general methods of planning, some of the typical tools and mechanisms used may be reviewed as to their place in a production control system.

In a broad sense, the process of production control involves five steps —planning, scheduling, dispatch, progress record, and follow-up.

First comes the making of a decision as to when an operation shall be performed. This involves a knowledge of the capacity available for production and of the relative urgency of the various orders to be produced. Once these plans are made, they can be embodied in a schedule and the man responsible for planning may turn over to subordinates the task of dispatching or giving out the orders at the proper time to workmen, foremen, or others responsible for immediate performance.

As the task is performed, it is customary to make a *progress record* showing where the record is and to what extent it is up to, ahead of, or

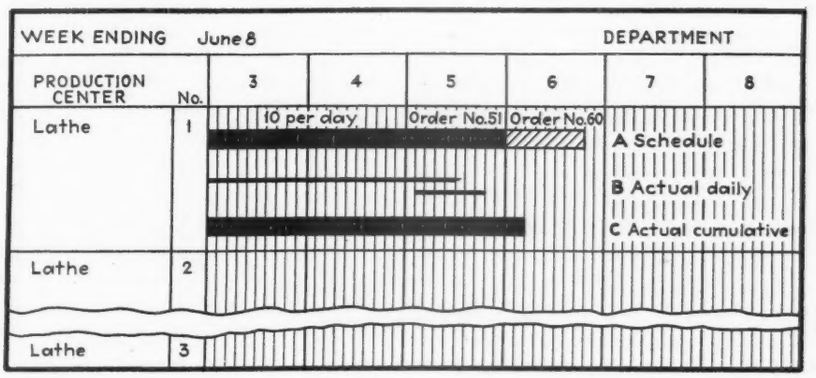


Figure 6. The Gantt chart in some one of its innumerable forms has often been called management's best planning tool

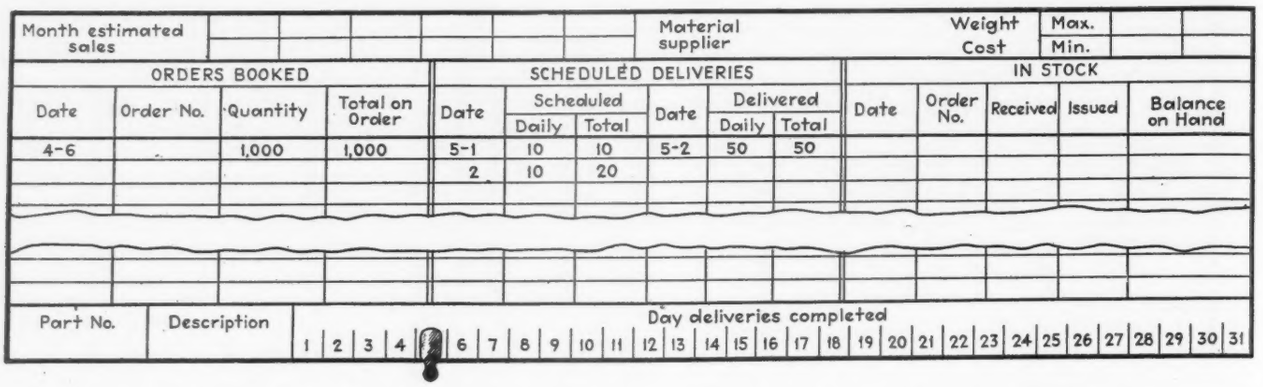


Figure 7. One widely used modification of the Gantt chart is the visible index record shown here in simple form

behind schedule. In quota schedules, such as those described, a common plan is to show the daily and cumulative actual deliveries against corresponding scheduled totals. With orders that do not follow a standardized and uniform path through the shop, the progress record may also, by showing the last completed process, indicate the machine or department at which the job may be found.

Gantt Chart in Control

The Gantt Chart is one widely used device both for scheduling and for showing performance against schedule. In Figure 6 the chart is divided vertically into working and time intervals, days, hours, or any other convenient unit. The horizontal divisions are for machines, departments, or any other process unit.

The top line (*A*) in the lathe department indicates the work scheduled against the department in terms of time. Thus, if the scheduled rate of output on the order shown were 10 per day, the line *A* would indicate a total schedule of 30 for the 3 days. If the next unit were produced at some other rate, say 50 per day, a line of the same length of 3 days would indicate a total schedule of 150 parts. The order number, and rate of output, are usually indicated at the commencement of each line schedule. Below line *A*, a second line, *B*, may be drawn to indicate the production each day. In this case 9 were produced on Monday, 15 on Tuesday, 8 on Wednesday. Line *C* shows the cumulative production to any given day. The extent to which line *C* falls behind or is ahead of any day or hour at which the chart is inspected, indicates its condition relative to schedule.

The Gantt Chart is valuable in giving a quick, graphic picture of actual as compared with scheduled production. This record is particularly useful in showing foremen where their departments stand, or in enabling the factory manager or other executives to see at a glance where the trouble points are. One company, during a rush period, photographed such a chart periodically and sent it out to its salesmen, to guide them in making dates and in concentrating selling effort on the departments most in need of work.

Gantt Modification

A simplified and convenient modification of the Gantt Chart is used in a visible index record shown in Figure 7. The body of the card carries the production order or orders scheduled against a particular product or part. The lower margin of the card (which, being hinged to the upper margin and "shingled," is the only part of the card that shows) bears the part number and is also divided into days or other convenient time units. A given quantity, as 10, being scheduled for daily delivery, a flag or marker on the lower edge of the card is advanced, as deliveries are made, a corresponding number of days' scheduled production. Thus, if 50 parts were delivered on the second day of the month, deliveries of 10 per day being scheduled to commence on the first, the card would show the orders 3 days ahead of schedule on that day. The comparison line, the current day of the month, moves one space to the right every day. Four days later, if there had been no subsequent deliveries, the order, instead of being 3 days ahead of schedule, would be a day behind. The follow-up clerk can tell by a glance at this card which orders are in need of attention.

"Exception" Control

The Gantt Chart gives an excellent visual record, which can be adapted to a wide variety of situations. But where times are known to a sufficient exactness to make a Gantt chart valuable, apparently follow-up can be handled on the exception principle, only those cases behind schedule being recorded, thus doing away with the continuous graphical posting of all production. Consequently the original graphical Gantt Chart is not in very widespread use for production control, although many modified applications, such as the above, are made of the principle.

Progress records are usually kept by routine clerks, who post deliveries, or cross off filled orders, as the time card, move order, or other document that shows their completion is received. The progress record is available to superintendents or any other interested persons, but is of particular importance to the follow-up men, who are usually assigned to check up on the routine processes of the production and planning departments and see that at no point does the order get lost or pushed aside beyond the requirements for delivery.

Follow-up may be of two types.

When unit times are known with sufficient accuracy so that delivery to schedule may normally be depended upon, only those cases that are behind schedule require attention. As time cards or other reports of completion are turned in, the clerk who receives them glances at the scheduled delivery date, often extended on the face of the order, and holds out for further attention only those orders behind schedule. This use of the exception principle effects considerable economies in supervision.

Where delivery dates cannot be set with certainty, due to lack of reliable time standards, or to frequent shifts in schedule, the common plan of follow-up is to assign every order to one of possibly several follow-up men, who check the progress of every order at suitable intervals, depending upon the urgency of the order, and take steps to accelerate the progress of any order that is not advancing satisfactorily.

CHAPTER EIGHT

Planning in Non-Repetitive Manufacture

THE STEPS of planning, scheduling, dispatch, progress record and follow-up are present to some extent in most cases. For the flow types of industry so far discussed, the general plan of control can be comparatively simple because for the most part large groups of processes may be treated as units. A majority of plants are of this type and present few difficulties in plan.

A more complex situation is met where there is no uniform flow of product. In a jobbing machine shop, for example, one order may go from lathe to boring mill to gear cutter; the next, from milling machine to lathe to drill press. It is no longer possible to schedule as a unit or for a balanced capacity, except in the most general sense for annual requirements. Parts take a divergent and irregular path through the shop. This week, half a dozen orders may pile up at the boring mills; next week these machines may be idle while another group of machines are loaded to capacity.

Every machine or small production unit becomes a separate scheduling problem, and orders are advanced as through a labyrinth of interweaving paths. It is no longer practicable to schedule the order from start to finish; the failure of any one process to meet schedule, or any minor adjustment of schedule to meet a customer's needs, would upset subsequent schedules not only on this order but on many others. The best that can be done is to see to it that at each machine or process the most urgent order is given precedence. If this is accomplished, and if, further, the schedule clerk sees to it that a "next job" is always ready for each machine with tools, materials, and supplies all checked up, about all that is possible in this type of industry in the way of scheduling will have been realized.

The Taylor planning board (Figure 5), which is met with in many forms, is probably the best method yet devised for handling this type of scheduling situation. In this plan a board or rack is provided with a set of pockets or clips, one for each machine. Supplementary pockets may be added for jobs in work and for jobs at other processes that will later come to the machine. As a job is delivered to a machine, to wait its turn for completion, a time card or other record of the order is placed in the pocket or under the clip that corresponds to the machine. If supplementary pockets are used, the time cards for subsequent operations may at this time be distributed to the supplementary pockets of the machines to be used.

Order of work at the machine is controlled by the arrangement of the cards in the pocket. As a man completes a job, he comes to the window and the dispatch clerk gives him the card at the front of the pocket. The schedule clerk is the only person authorized to change the position of the cards, but he can do so at any time, keeping the board lined up to meet the changing situation of customers' needs and rush jobs. A general right of way may be given a rush order by pasting a special sticker to its face or stamping it "rush."

How to Show Progress

In connection with the Taylor planning board and its various derivatives, a progress record is usually kept to indicate at what machine a job may be found. One method of doing this is to file by part or order number an original

LIST OF MATERIAL REQUIRED PER UNIT

Quantity	Description	Symbol-Part No.
2	Side rails	441 B 1
10	Cross slats	441 B 2
9	Braces	441 B 3

DESCRIPTION Spring base PATTERN NO. 441 B

ORDER NO	11,268
DATE WANTED	6-3-35
DATE PLACED	5-2-35
DATE FILLED	
QUANTITY	100
QUANTITY AND DATE DELIVERED	

ORDER NO.	DESCRIPTION OF TOOLS	DONE AT MACHINE NO.	HOURS PER UNIT	DRAWING TOOLS	
1	Set for riveting	119	0.1		5-8-35
2					
3					

Figure 8. In connection with the Taylor planning board (Figure 5) a progress record shows where a job may be found at any time

copy or duplicate of the route sheet or process analysis for the job. See Figure 8. As the time card or other record of completion of each operation is received by the planning department, the corresponding operation is checked on the route sheet.

Can Care for Details

The Taylor planning board is most effective in controlling groups of not over 200 or 300 machines, although not necessarily limited to this number. Effective scheduling, however, requires a continuous intimate contact with details. The schedule clerk must know, for example, that of several nominally identical machines one has been fitted up to take a special chuck developed for the job, that the operator of another does particularly well on certain types of work, and similar differences which shift from month to month and can be handled at long range with difficulty, if, indeed, they can be handled at all. As an essentially local means of control, the Taylor type of board is well adapted to the use of foremen, when the amount of detail in the department is sufficient to call for systematic controls.

CHAPTER NINE

Relation Between Budget and Day-to-Day Scheduling

UNTIL quite recently, the tendency was to regard the general sales forecast and budget as entirely separate matters from detailed planning. The budget was made once or twice a year, served as a basis for general plans such as the purchase of new equipment, was compared periodically with operating results, but was otherwise not tied in with day-to-day operations. The tendency toward combined scheduling and budgeting, already mentioned, is reacting to influence the budget as well as the production schedule.

Sales Are Budgeted

A large hosiery manufacturer, for example, budgets production and costs for six months in advance. This is not merely a general budget, but a detailed estimate, item by item, of expected sales. The data for this estimate are gathered by the sales department after consulting individual customers as to their probable needs. Production quotas or releases based on these estimates, but covering at the start only, say, 40 per cent of the total expected sales, are issued to the factory.

As the season opens, the trend of actual sales is compared with estimates, and the quotas are increased or decreased to correspond. Sales to date have shown an unexpected increase over last year, but even with this variable factor, sales and costs are running within a few per cent of budget. Although final certainty is of course impossible, the modern method of detailed analysis of customer needs, with corrections based on indicators of general business conditions and on factors such as the drought that will influence local demand, is yielding for many firms estimates of sales that may be relied upon within a few per cent. The value of such estimates in making purchase commitments, arranging schedules, providing for financing and otherwise controlling production operations to the best advantage is obviously great.

It is of course easier to make such predictions where one serves a large number of consumers, as does this hosiery manufacturer, than where the bulk of the business is in large occasional contracts. In the capital goods industries the rule is still to provide plenty of reserve capacity in the way of plant and capital and then to go after the orders.

One effect of the tendency to integrate the budget and the production program has been to coordinate departments that were often in the past largely self-sufficient. The purchasing agent of today, for example, while he has important responsibilities in advising as to probable price trends and in securing advantageous sources of supply, is governed as to deliveries by the monthly and daily production quotas. In fact, once the contract with the supplier is signed, further correspondence as to releases under the contract is often transferred direct to the production department.

The National Electric Coil Company, Columbus, Ohio, uses this control board to good effect. A white strip for each job is mounted under the day on which the work is to be completed. This strip is marked off by operations, with the calculated time for each operation indicated. A narrow black band is drawn down over the strip as the work progresses, thus giving the status of any job at a glance. Colored tabs at the foot of the white strips indicate whether job is rush (red tab), promised for a certain date (blue), etc. The pigeonholes along the bottom of the board are for job tickets and other data

CHAPTER TEN

Economic Factors in Production Control

IN ADDITION to the question of lot size and the relation between set-up costs and the plan of production control, the choice of a production control system may be considerably influenced by the balancing of several other cost factors.

There is, for example, a relation between the cost of equipment, the plan of layout, and the system of production control. In the straight-line plan of machine arrangement, where the order of processes is fixed and the equipment is generally balanced, at least approximately, a very simple and direct production control plan is possible. If the orders are fed to the first process at the right rate, they can be depended upon to travel to completion with little or no attention except to see that there are no hold-ups along the way.

On the other hand, unless there is enough work to keep each straight-line unit busy, this plan may involve a considerable waste of machine capacity as compared with the so-called functional plan, in which machines of like kind are grouped into departments, the work follows no uniform sequence of processes, and the more involved and less effective methods of non-repetitive scheduling must be resorted to.

Balance Layout with Control

During the depression many firms found themselves with more machines and floor space than they could get work for. The disadvantage of carting orders from one department to another, personally conducting each order through the entire process by means of a Taylor type of planning board and signing in and out for it between each department stood out with startling clearness as orders became smaller and more occasional. On the other hand, machine capacity stood idle, and machines could be had for the asking. Many firms saw the point and took out from their functional departments enough machinery to set up balanced units. When the company has an order for draft arms, the draft-arm unit is started and the order run out, rather than starting the forging department, the machining department, and the assembly department.

Change Back with Better Business

Presumably the balance will shift back somewhat as plants get busier. But the reduction of inventory and of clerical, material transportation, and other costs involved in the functional system are so considerable with flow production that some portion at least of the shift from the functional plan of layout and manufacture is likely to prove permanent.

This shift, indeed, may be expected to influence not only production but also sales plans. The lower cost of flow production and its greater speed of delivery tend toward the segregation of similar types of work to secure this advantage. This may mean concentration of fewer lines and the elimination or purchase and jobbing of small and special lines, or the setting up of entirely independent units, one equipped for straight flow production, the other taking and handling on a job-shop basis all the small, special, and fussy items. This separation in turn puts the spotlight on the higher costs of special production, results in better price policies and again tends toward the elimination or farming out of the special items to other firms that specialize in such work.

The interrelation of production with other economic factors may be illustrated by another example. The more complete the system of production control and exact the standards on which it is based, the smaller the margins both of inventory and of capital and equipment with which it is safe to operate. There is again a choice, and presumably a point of lowest unit cost, between the policy of operating with large reserves of material, equipment, and finished inventory and the policy of closer and more detailed control at higher cost.

In this connection, however, it must be noted that, while the costs of more exact control tend to rise sharply during the first stages in obtaining such control, they usually drop when the control becomes more complete. At first, there is the long, expensive job of standardizing materials and operations, setting standard times, and accustoming the force to an unfamiliar routine.

Since the standards are at first quite apt to be unreliable at times, the old methods of material chasing must to some extent be continued in parallel with the new plans of control. The work of standardization and control is quite apt to be abandoned during this discouraging stage. If this stage is passed, however, schedules become more and more dependable and require less and less time for follow-up. Incidentally, one byproduct of the initial stage of analysis is often the discovery of improved methods and savings which may offset the costs in other directions.

Depression Simplified Systems

During the depression period, with its reduced sales and urgent financial problems, comparatively little attention has been given to improvements and innovations in the field of production control. There was little production to control. The experiences of this period have, however, brought out more clearly than ever before the interplay of the various factors to be considered in designing a good system, adapted to the needs it is designed to serve. A good many unnecessary elaborations and faddy frills have disappeared, let us hope forever.

While there will continue to be businesses, a good many of them, in fact, that must rely on stock limits and individual process scheduling, it is clear that the trend will be toward the greater exactness and economy of budgeted production. Future progress in production control is likely to be in the direction of extending this control and making it applicable to the more irregular and unpredictable fields such as jobbing and machine production, as well as to the consumers' goods fields in which it is already well intrenched.

CHAPTER ELEVEN

Typical Plans

Case One

This company builds a wide variety of machinery and materials handling equipment, some of it standard but manufactured to order because of the comparatively large investment per unit, much of it specially built to the customer's needs.

Bills of material are made up for each customer's order and checked against balance of stores records. Standard unit parts are manufactured primarily to stock-limit control; parts orders, therefore, originate for the most part with the stock clerk, as balances on any part reach minimum.

From the bills of material, after check against stock, shop orders are written in copying ink, a line being given to each item or part on the order. Copies of this order are run for each foreman concerned in filling the order, also for the cost department, shipping department, and engineering department.

A copy is also run on a special route sheet form, and a process analyst or route clerk analyzes each item and lists for it the processes required for its manufacture.

Paperwork Is Mechanical

From the original order, one item at a time (the other items being blocked off on the copying machine temporarily), enough copies of material requisitions, time cards, identification tags, and other required forms are run to supply the operations indicated on the route sheet. This work is all mechanical after writing the first copy, except the routing and the filling in of machine number, allowed time or piece rate, and a few other details on the time cards and identification tags. Clerical costs are consequently low.

After the time cards have had the rates and machine numbers filled in, they are filed in a reserve file until the return of the signed requisition indicates that the material has been delivered and is ready for work. The time card for the first operation is then drawn from the file and placed in the proper machine pocket of the Taylor-type planning board, the position of the card in the pocket determining the order of the various jobs at the machine.

When the job is finished, the time card is stamped with the completion time—the starting time having been entered when the job was given out—and the movement of the job to the next operation is checked on the route sheet (see Figure 8) which now serves as progress record. The time card is taken out for the second operation on the item, placed in the proper machine pocket, and handled as before—and so until the job is finished.

On a blackboard in the planning

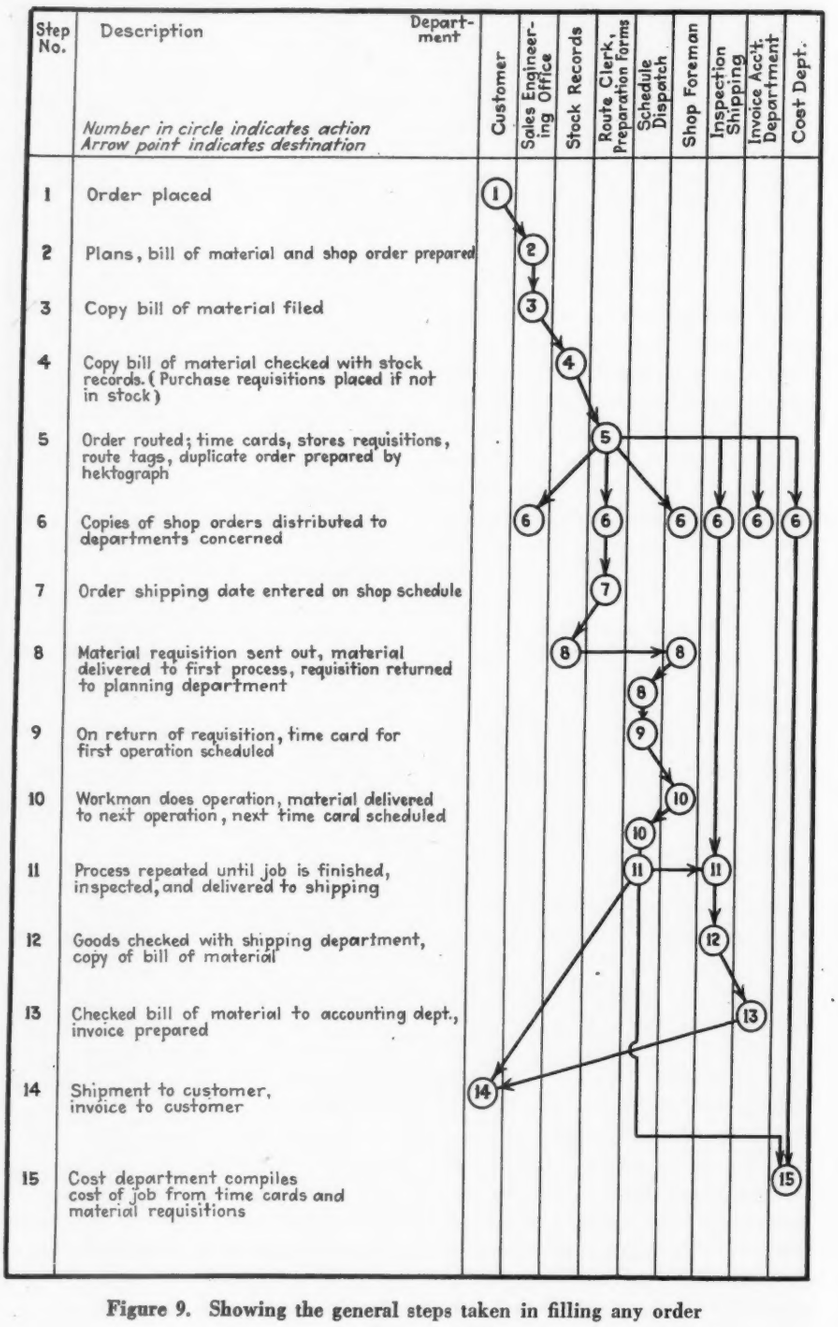

Step No.
Description
Department
Number in circle indicates action
Arrow point indicates destination
Customer
Sales Engineering Office
Stock Records
Route Clerk, Preparation forms
Schedule Dispatch
Shop Foreman
Inspection Shipping
Invoice Acct. Department
Cost Dept.
1 Order placed
2 Plans, bill of material and shop order prepared
3 Copy bill of material filed
4 Copy bill of material checked with stock records. (Purchase requisitions placed if not in stock)
5 Order routed; time cards, stores requisitions, route tags, duplicate order prepared by hektograph
6 Copies of shop orders distributed to departments concerned
7 Order shipping date entered on shop schedule
8 Material requisition sent out, material delivered to first process, requisition returned to planning department
9 On return of requisition, time card for first operation scheduled
10 Workman does operation, material delivered to next operation, next time card scheduled
11 Process repeated until job is finished, inspected, and delivered to shipping
12 Goods checked with shipping department, copy of bill of material
13 Checked bill of material to accounting dept., invoice prepared
14 Shipment to customer, invoice to customer
15 Cost department compiles cost of job from time cards and material requisitions

Figure 9. Showing the general steps taken in filling any order

department is a list, in columns by days, of the delivery dates of all orders in the shops. As fast as a job is shipped, it is crossed off on this chart, in white chalk if on time, in red if late. The condition of this chart shows at a glance where the hot spots are. Follow-up men check the progress of individual orders. Figure 9 shows the general steps taken in filling an order.

Case Two

This company manufactures small electric motors, in lots of from one to thousands. Motors may be standard, standard type modified to meet customers' needs and ideas, or special.

Unit parts such as field and armature stampings, bearings, brushes, and the like are usually made up to stock, which may be controlled either by a requirement sheet such as Figure 1 or by stock limits.

Winding and assembly are done usually only to customer's order. Small lots are turned over to a "repair and special" department where they are built on a jobbing basis. Larger orders are manufactured on a conveyor line, the order of processes being practically uniform. Each lot is accompanied by instructions. As it reaches the armature department, for example, the operator will refer to the instructions for details as to style of winding. In many departments, such as painting and insulating, special instructions are not required.

After the final test and run-in, performed, by the way, on a conveyorized basis in step with the preceding processes, the motors are checked against a shipping room copy of the production order, packed, shipped, and invoiced in the usual manner.

Case Three

This company manufactures electrical equipment, usually sold in large installations requiring switchboards, instruments, and a large number of separate units in variable proportions. With few exceptions, the equipment is standard, although specifications are changed from time to time. Several thousand different items are manufactured. Sales are not particularly seasonal, but many sales are in large orders taken at irregular intervals.

A general sales estimate or budget aids in the making of general plans. As orders are received, they are broken down into parts requirements, which are posted to records on the principle of Figure 1. On the basis of ordered and anticipated requirements, schedules are issued to each department head, calling for the delivery of lots of parts, either at daily rates or at one time, at a rate based on the known capacity and work ahead of the department, and on the requirements of the job. The foreman may ask for a longer time in which to make delivery in case he thinks he cannot meet the schedule; if he accepts it, he is responsible for meeting it or giving immediate notice of any interruption. He can arrange the work in his own department in any way that meets schedule.

Deliveries are entered daily at the central planning office and compared with requirements, any interruption not reported by the foreman being thus caught and followed up.

Case Four

Radio and refrigerator manufacturer. This industry is characterized by large runs of a limited number of models. Models are subject to frequent and sudden changes, as competitors bring out new models or the company's own research department develops improvements. Demand is seasonal; the seasons for the two products being complementary.

For each of the models decided upon for a season, an estimate of probable sales forms the basis of a weekly release, of a quantity and for a duration determined by the sales estimate. This schedule is translated into a detailed quota of daily deliveries for each department, constructed on the principle illustrated in Figure 2. The quotas are also extended on the basis of the known costs for time, material, and department expense to give an operating budget for the department.

The purchasing department operates to a schedule of material releases similar in principle to that used by the operating departments and is, like them, responsible for meeting accepted schedules. Very few parts are carried in stock; the risk of change of models is so great that the aim is to clean up the entire stock of parts for a model at the end of every run.

New schedules are released monthly, a week in advance of the expiration of the old. Should the sales of any model prove disappointing, schedules for this model would be shortened so as merely to use up the materials for which firm orders had been placed.

Schedules and budgets are made up in a central planning department. Deliveries are also reported to this department. A foreman may run somewhat, although not too much, ahead of schedule but is expected not to get behind, except for good reason.

Case Five

Steel mill, rolling stock to customer's order.

No stock is carried except basic raw materials. Customers' orders are in general filled in the order received, except for small lots, which are accumulated until there is a sufficient quantity of a particular alloy composition or type, to justify setup. Ingot heating and rolling are controlled by a simple list of jobs to be run each day.

Case Six

A large firm of printers, handling job, catalog, book, magazine, and miscellaneous work.

Each job, as sold, is put in charge of a "correspondent" who becomes responsible for delivery and general satisfaction of the customer and who works closely with the salesman on the job. A correspondent may handle the business of only one large customer, or may look after a long list of small and transient accounts.

Scheduling of the shop's capacity is done by a chief schedule clerk, who maintains a planning board of modified Taylor type. The capacity of composing rooms, presses, stapling and stitching machines, and other units is allotted as usual on

this planning board. Since all questions of order of work are settled in this department, the needs of various correspondents are reconciled in this department, in consultation with the superintendent if necessary, and are not allowed to disrupt the work in the shop without good reason.

Certain large orders, in practically continuous production, are operated virtually as independent flow units, and can be disregarded in day-to-day scheduling.

Case Seven

Bakery — cookies, crackers, and sweet goods. Demand for many of these items is seasonal, as for Christmas cookies or oyster crackers.

Large stocks of flour, lard, sugar and other raw materials are carried. Finished goods, being perishable, are made only on order or to a limited extent in anticipation of immediate call. Daily and weekly schedules are issued to cover these requirements. On the basis of these schedules, the mixing foreman sets the dough a day in advance, and at the end of the day the foremen of the cutting, baking, and packing departments make such changes in dies and machine set-ups as may be needed for the next day's run. Deliveries are tallied against orders and shipped to the customer, a very limited amount of follow-up work being required to take care of delays, oversights, or bad runs.

Production fluctuates from week to week in this business, and the company has developed to handle peak load a neighborhood clientele of married women, who can combine part-time work with their household duties to advantage.

Case Eight

Manufacturer of scientific instruments. Nearly all of these are standard patterns, sold from year to year with only slight changes. Sales of some items may amount to only two or three a year, while others are manufactured at the rate of many thousands per year. Sales are seasonal to a slight extent. A rather miscellaneous equipment of wood- and metal-working tools, hand bench work, and precision assembly and testing is required.

Except for special orders, stock limit control is used almost entirely in this case. Production is regularized by frequent consultation between the chief storekeper and the factory manager, and by the device of the double minimum already mentioned. Stock limits are revised frequently; the record of use, the seasonal trend, price trends, and sales prospects determine the limits set. To a large extent, both parts and sub-assemblies of all stages are separately stocked, since a particular job may require the combination of units that may be used in several other combinations.

Manufacturing orders are issued in different colors, one for customers' orders, another for stock orders, another for "urgent" or second-limit stock orders. Each order lists the entire sequence of processes required for manufacture. A copy of this order is kept in the office and serves as a progress record, being checked as each operation is reported completed. The original of the order travels with the material and serves as an instruction and move order. No planning board is used. The workman records his time on jobs on a daily time card.

Case Nine

This plant manufactures oil filters —about 175 different types—for automobiles, oil burners, etc.

To control production, a simple board is used. It is divided into vertical columns representing days of the month. Each column in turn is divided into two narrower columns, one for daily production totals, the other for running totals. Incidentally the dividing lines serve as quantity indexes, 50, 100, 150, and so on.

Models are identified by horizontal lines. Name and stock number are set down at the left; number on hand on the first day of the month appears in the next space. The spaces formed by the horizontal lines are in turn divided into three equal spaces. Thus for each day of the month, there are six spaces in which to record information. The upper two show daily and running totals; the bottom two, the number manufactured and ordered on that day. The two middle spaces show discrepancy, if any, between orders and stock.

Two colored pins complete the picture. A blue pin stuck, say, in the 500 line shows number of the particular model in stock. A yellow pin—stuck, say, in the 400 line—indicates orders for that number, and shows that production is 100 ahead of orders. At all times, therefore, the relative positions of the pins shows at a glance where production stands on any one of the 175 models.

Color Tells All

Similar boards control stock. See Figure 10. Minimum and sub-minimum points are set for each item. The board is divided vertically to indicate quantities — 500, 1,000, 2,000, etc. Horizontal columns indicate parts. For example, a red crayon marking on the 4,000 mark in the column for No. 1205 bolt shows that 4,000 has been set as the minimum number of these stock bolts to keep on hand. Similarly, a blue mark on the 2,000 line, halfway between the minimum and the zero marks, indicates the sub-minimum or extreme danger point.

Again, colored pins are used to give a quick picture of the condition of stock on each item. A green pin

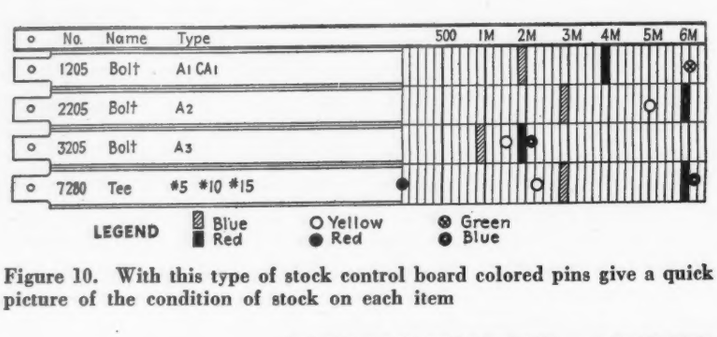


Figure 10. With this type of stock control board colored pins give a quick picture of the condition of stock on each item

stuck in the 6,000 line shows a margin of 2,000 bolts. If an order comes through for 3,000, the green pin goes back to the 3,000 mark, 1,000 below minimum, and the clerk immediately places an order for 4,000, the minimum number. The green pin comes out and a yellow one goes in, indicating that the order has been placed. Then if further depletions of stock bring the total down to, say, 1,000—below the sub-minimum—a red pin replaces the yellow one, indicating that immediate follow-up of the order is necessary. If the order arrives on time, as it usually does, the pin moves back to 5,000, becomes green again. One further check—this one to be sure the order is actually placed—is furnished by a blue pin that is placed at the minimum mark when the purchasing department's confirmation of the order comes through.

One girl runs the boards. Ordering becomes largely automatic. Inventories are kept at the lowest figure consistent with production requirements.

Case Ten

A shoe manufacturer who makes three grades of men's shoes in the same factory, stocks them in 150 or more styles, many of them in 7 widths and up to 116 sizes.

A perpetual inventory of shoes on hand is kept. Sales are deducted twice daily. To it are added shoes gone into the works, giving a new total every morning and every afternoon, and presenting a manufacturing picture that is within half a day of actual sales.

Twice a day a "list" of shoes to be made goes to the cutting room. A list is a half-day's work—100 dozen pairs, no more, no less. Twice a day, therefore, the factory receives orders for 100 dozens.

Each list is made up so that every single lot of shoes on it will move through the factory as part of a steady stream of production—so long in the cutting room, so many days in the fitting department, etc. In other words, the lists move through in waves, each entering and leaving a department as a unit.

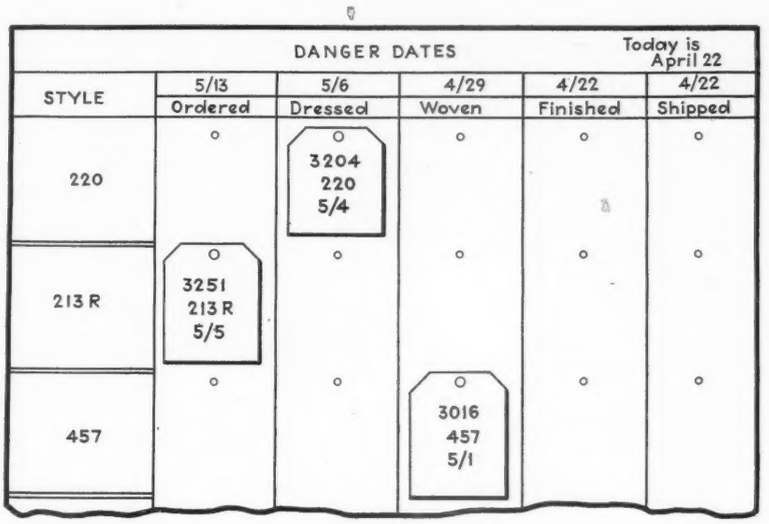


Figure 11. Location of orders is checked daily at production centers

To maintain this steady flow of production, various important factors are taken into consideration—proper balance between the various grades of shoes, ratio of machine-cut to hand-cut shoes, number of bluchers, amount of perforation and heavy stitching, number of sport oxfords, supply of lasts, and so on.

To insure that soles, heels, and other supplies will be ready as needed—even the customer's own labels for the cartons—duplicates of the original work tag go to a dozen or more points in the factory.

Mechanical handling, incidentally, is tied in closely with the larger job of planning in this plant—as it should be in any plant. Conveyors and elevators, the latter semi-automatic, make it impossible for a foreman to blame his failure to get out production on his inability to get shoes down from upstairs or up from downstairs.

Case Eleven

A production control system which has been installed in a number of woolen and worsted mills consists simply of checking the location of orders daily at important production centers. The plan can be readily adapted to plants in other industries.

Checking points in one mill where it is installed are: (1) Order received; (2) dressing; (3) weaving; (4) finishing; (5) shipping.

A ticket is made out for each piece as the order is received. Tickets show style number, piece number, and date of shipment. There are hooks on the production board, and tickets are placed in the "ordered" column (see Figure 11) by style number—all tickets with same style number on same hook, the ticket with the earliest date on top.

Each day the clerk gets a report from each department and moves tickets accordingly. Thus at any time the exact location of an order is determined at a glance.

There is a further refinement—the use of "danger dates." Today is April 22. To make the illustration as simple as possible, let us say it takes three weeks to ship an order—one week each to be dressed, woven, and finished. It follows that a piece ordered today can safely be promised for May 13 delivery, and to keep that promise it must be dressed not later than April 29, woven by May 6, finished on May 13. Today's date is therefore set down in the "finished" and "shipped" columns, and advanced one week for each of the three preceding departments.

Now the board works like this. If the delivery date for a piece is the same as the danger date set above the department in which it is at present located, the piece is on schedule. If the delivery date is *earlier*, it is behind schedule; if *later*, it is ahead.

Referring to the figure, No. 3204

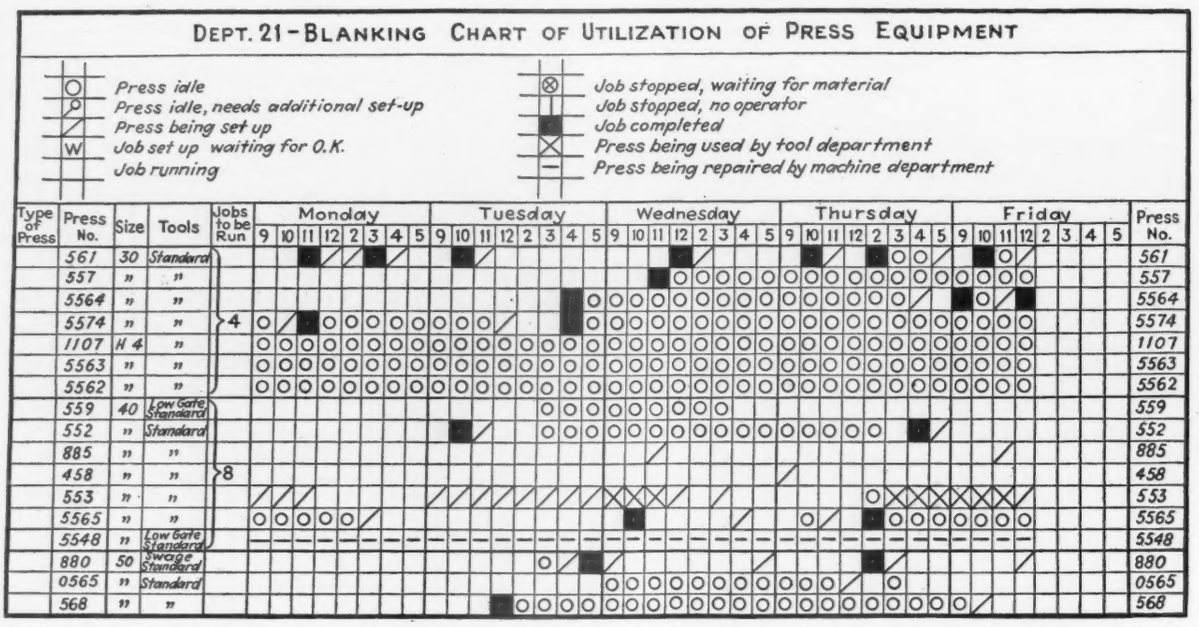


Figure 12. An up-to-the-hour record of machine utilization warns of production conditions that need improvement

calls for May 4 delivery. That date is earlier than the danger date, hence the piece is two days behind schedule. Figure it out. Today is April 22; it takes a week to weave and a week to finish, so delivery cannot be made until May 6. Piece No. 3016, on the other hand, is ahead of schedule; delivery is promised on May 1 but can actually be made in a week's time—on April 29, two days sooner than asked for. Obviously, piece No. 3251 (which just went into the works today) will take three weeks to process, so cannot be delivered until May 13 if it follows the regular production schedule. Someone will have to do something about that.

Case Twelve

Small parts of an electric switching device, made in quantity. This plan, described in a previous issue of *Factory*[1], has unusual production control features.

Parts for the sequence switch used to be made up on order by functional departments, such as punch-press departments, assembly departments, and the like. It was found that the item was being called for in volume sufficient to justify the operation of a balanced flow unit. Machines were grouped in the new department approximately in the order of processes, and as nearly as possible in balanced capacity. A roller conveyor encircled the room, was kept in motion by a light motor drive. At each machine line a spur with a keyed switch took off.

As raw material was made up, the processed parts were placed in tote boxes. These boxes were keyed so that the selective switch on the main conveyor line would shunt them off at the next process. The next process completed, the workman shifted the key stubs, say from position 2 and 5 to 3 and 5, and the box went to the next process.

If a particular machine was supplied with raw material or parts, the conveyor spur would reject tote boxes until there was room for more on the spur; the finished material would simply circulate round the conveyor until it was needed. The length of the conveyor was calculated to hold a month's supply of parts.

The plan eliminated all orders, transfers, and accountings necessary when the work moved through several departments. To see how the work was progressing and to start new lots of parts, the foreman had only to check final deliveries and look over the stock on the line.

Additions of new equipment could be made easily with a line of this type simply by extending the conveyor. The system of keying eliminated the need for any special order of machines.

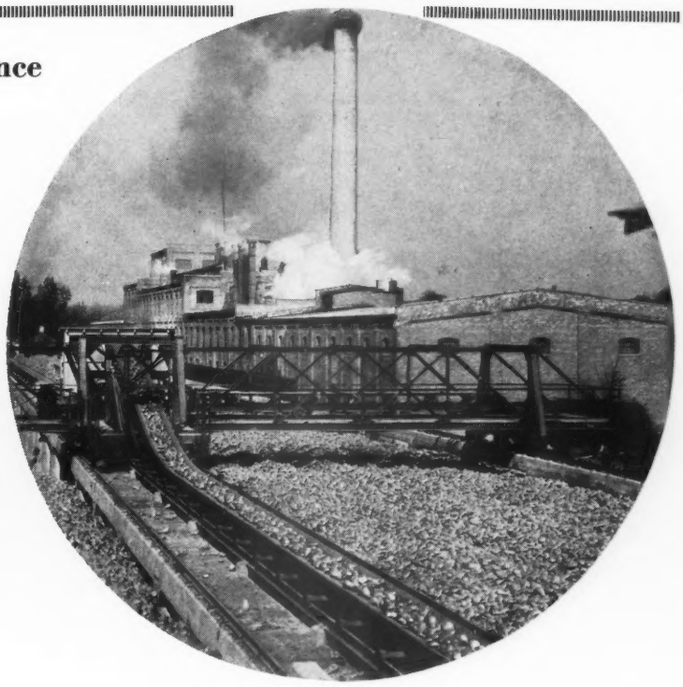
Case Thirteen

A concern whose products—mainly harness hardware and clothing buckles—have a short and simple manufacturing cycle. Once the articles are cast, formed on a wire machine, or blanked on a power press, they can be finished, packed, and shipped very quickly.

Originating departments are therefore all-important. In the blanking room, for example, are 52 power presses—adequate in point of numbers for production requirements. To keep them adequate, a utilization chart (Figure 12) has been devised. From its up-to-the-hour record of operation, the superintendent is warned of conditions that need improvement. It answers such questions as: How are the presses loaded? What presses are idle and why? Is additional help warranted? Has press number so-and-so, with several "back orders" waiting on it, been repaired yet? Are the toolmakers quick in setting up new jobs? Are production men scheduling the longest possible runs?

[1]Latest in Layout Did This to Costs, by R. H. Patchen. February, 1935.

Factory Management and Maintenance
Plant Operation Library



MATERIALS HANDLING

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Open-Door Handling Policy Essential to Successful Plant Operation

NECESSITY demands that every alert manufacturing plant observe the open-door policy in regard to materials handling equipment.

Each unit of each industry must take advantage of all the available technological development in methods and equipment in order to satisfy the economic requirement of this machine age. That requirement is low-cost production in the interest of widest distribution, greatest prosperity, highest individual net profit.

To *have,* in short, we must *make.*

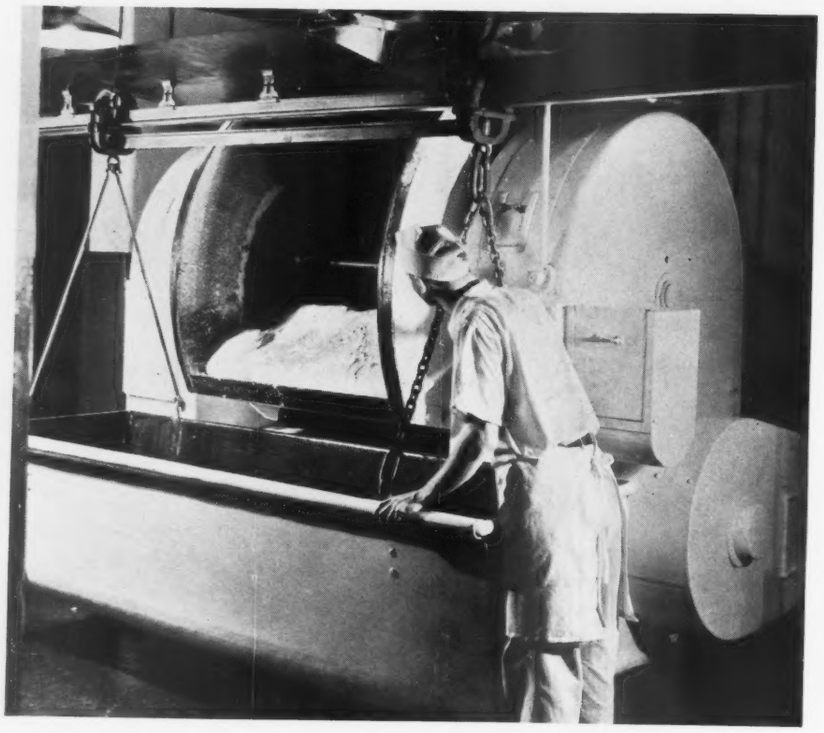
As the products, processes, and volumes of business change, handling methods must change with them.

Plant layouts are constantly being revised to meet new production requirements. They economize travel of parts, motion of personnel. They call for revised methods of handling.

As costs of labor and materials increase, mechanical handling becomes more and more advantageous. As profit margins narrow, the manufacturer finds it pays to reduce manufacturing space—or to get more production out of a given space. He does it with the help of the right handling equipment.

Man produces least when he is wasting physical effort. For instance, when he is moving materials. Handling equipment lightens tasks, improves efficiency of workers. It cuts down non-productive time of productive workers, decreases idle machine time, increases output both of man and machine.

Reduction of process time, of process inventory; acceleration, coordination, stabilization of production; more positive scheduling, kept delivery dates; protection of semi-finished and finished goods—the recital of the advantages of mechanical



Right layout and right handling equipment make an 11-man plant out of Williams Bakery, Wilkes-Barre, Pa. Hourly production, 2,000 loaves

handling might well go on and on.

The marvel of it all is that the advantages of mechanical handling still go unheeded in many and many a plant in the manufacturing industries.

More Work for More People

Blame it partially, perhaps, on the fact that handling equipment invariably displaces men—and on industry's very commendable hesitancy to take any step that seems to lead directly to more unemployment. The answer lies in the knowledge that the introduction of labor-saving equipment is economically sound, that the best guarantee against technological unemployment is the introduction of more technological improvements. The pages of industrial history are full of proof that in the long run they give more work to more people.

This is not to deny that materials handling equipment may not for the moment deprive men of their jobs. This is not to imply that management may calmly turn people loose. It is merely to say that management's first job is to make its products at lower cost so that more people can buy more of them, that in the pursuit of that purpose it must take advantage of every available technological improvement. In each case, what to do about those who are "freed" for other jobs becomes a part of management's over-all responsibility to its workers. It is a responsibility definitely to be faced if technological development is to continue. Continue, it must.

Again, the failure to make fullest use of the newest and best in handling equipment may be laid to the fact that handling costs are frequently *hidden* costs. They lurk insidiously in indirect payrolls, are often buried in burden.

Yet it is so easy to spot many of these "hidden" costs.

Here two or three men are lifting work to a machine. There an operator paid to do productive work is doing ordinary handling jobs. Worse still, perhaps, a machine waits for materials. Worst of all, something is being handled when no handling is necessary.

Or, handling equipment may obviously be obsolete. A Pennsylvania concern pensioned off a team of oxen only a year or two ago. Again, there are the places where gravity could be used but isn't, where backtracking is so obviously unnecessary, where materials are sidetracked for inspection or other purposes.

Those are a few of the plant signposts that point plainly to unnecessarily high handling costs.

How Other Plants Handle

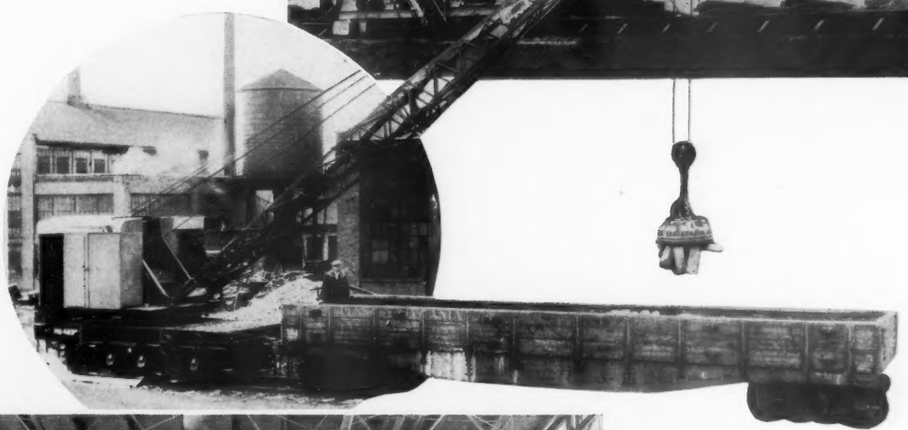
To help industry heed the signs, *Factory* adds this special materials handling section to its Plant Operation Library. On the well-supported theory that when it comes to transferring ideas a picture is worth 10,000 words, approximately half of the pages that follow are given over to photographs of actual plant installations. Their purpose is to show how other plants have solved specific handling problems, to suggest how you, too, may use the same equipment in your own plant.

To bring plant operating men up to date, the principal developments in handling equipment during the past four or five years have been detailed. A brief summary of recent trends in plant layout—with special reference to the effect on materials handling—serves to focus management's attention on that important phase of plant operation.

Last, a Materials Handling Check Chart — first of its kind — is appended to assist plant operating men in their selection of the right equipment for the job that has to be done.

Somehow the idea has grown up that mechanical handling may be brought to the point of highest usefulness only in the big plants where processes are continuous, where manufacture is repetitive. Perhaps it is not to be wondered at. Some of those big plants have developed new applications of handling equipment at so prodigious a pace that other manufacturers have come to the conclusion that there is some inherent connection between handling equipment and mass production. That is not so. There is nothing exclusive about the type of industry that can use materials handling equipment to its everlasting profit.

CALL THE CRANE



Especially adapted to outdoor service, where overhead runways are either economically or physically impractical, is the traveling gantry crane whose long legs can straddle railroad tracks and storage piles. This one handles sulphur at the Freeport Sulphur Company's plant, Grande Ecaille, Plaquemine Parish, Louisiana

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For such jobs as loading or unloading pigs, the gasoline, electric, or diesel locomotive crane—this one happens to be gasoline-powered—combines the advantages of one-man operation with adaptability to either intermittent or constant operation

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Increased handling speeds are one requirement of modern manufacturing which crane builders have been quick to meet. This 25-ton crane in the transformer assembly department of a large electrical manufacturing concern is provided with an auxiliary hoist for handling light loads in the assembly of transformer parts

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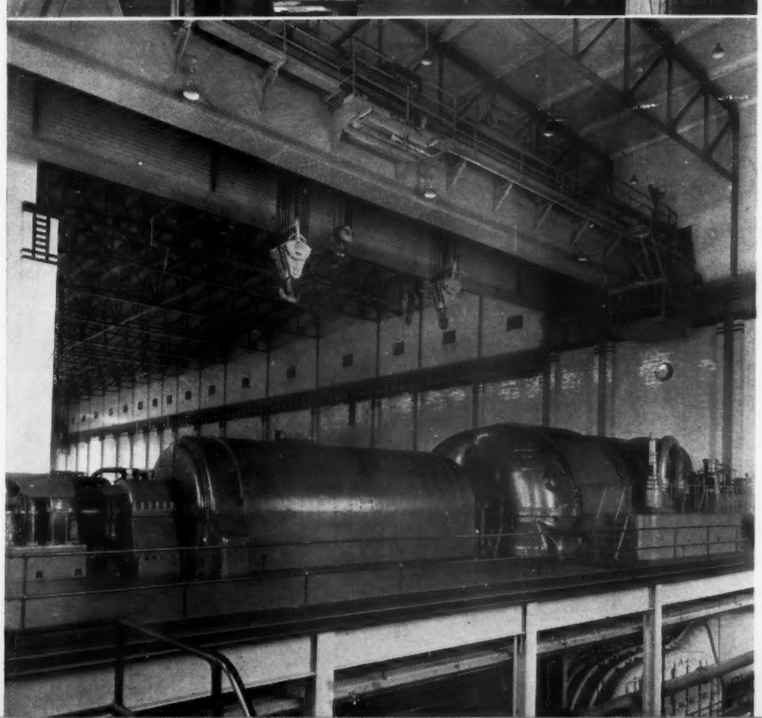


First piece of equipment to go into the turbine room of a power plant is the overhead traveling crane. Used originally to erect generating units, it then becomes an indispensable tool of maintenance for such heavy jobs as removing the top half of a turbine casing and taking out the spindle. This crane, of 250-ton capacity, has a span of 133 feet, a lift of 65 feet, is in Waukegan Generating Company's plant, Waukegan, Illinois

Equipment Developments Make Handling a Keener Cost-Cutting Tool

"TELL US what you have to handle and we'll show you how to handle it," might well be the boast of the equipment manufacturers.

Plant operating men who have not gone into the market for materials handling equipment during the past four or five years are overdue for a big surprise. Equipment manufacturers have not been idle. Not that startling innovations have been made, but noteworthy developments are to be found all along the line—developments that broaden fields of application, meet today's changed production requirements, spell lower operating and maintenance costs.

A complete list of developments would mean cataloging the dozens of items about handling equipment that have appeared from month to month in *Factory's* Equipment News Section. It is therefore possible to include in this current treatment only enough of the principal developments to indicate general trends.

Cranes and Hoists

One hoist manufacturer reports as additions to one line a twin-hook hatchway hoist, two new motor-driven trolleys, two new light-capacity hoists. In another line, there are no innovations in basic design, but many improvements in accessories and electrical features—among them a selective 5-speed, single-pushbutton control, contactor-type reversing switch, new safety limit switches, new electric brakes, two-speed motors, also new hoist frames providing for inclosure of wiring.

Another manufacturer of cranes and hoists cites roller bearings, welded steel construction. Much stress has been laid on insuring oil tightness and improving design to meet heavier service demands, increase handling speeds.

Complete redesign is cited by another concern. Hoist frame is now made of rolled steel plate welded to form a boxlike structure which is lighter and stronger than cast frame. Heavy-duty roller bearings replace bronze bushings. Same concern has also developed a new multiple-disk motor brake actuated by a sliding cam from controller shaft or by an electric solenoid.

Outstanding items in a fourth line are four hoists of aluminum alloy, from ¼-ton to 2-ton capacity. Net weight of first three sizes is about one-third less; in the 2-ton size, about one-half. Another feature of this hoist is a safety overload governor. When overloaded, handwheel continues to revolve, load remaining stationary.

Biggest development in locomotive cranes is installation of diesel engine, according to a manufacturer who offers 15- and 20-ton gas, electric, or diesel units, mounted on 8-wheel car bodies.

Important improvement in one line of portable cranes is a friction brake which insures positive safety to operator and load. Operator winds load up and down.

Another manufacturer offers tractor crane that may carry extra weight as counterbalance, thus increasing capacity. Same model has "power topping" boom, which means that position of boom may be changed because of head clearances. Load is lowered to floor with boom.

Pallets, now used with tiering trucks, are light, relatively strong, inexpensive, distribute weight uniformly when loads are stacked

Conveyors

One manufacturer has made improvements in troughing and return idlers that result in an idler pulley concentric as to shaft and permanently aligned with other idler pulleys. All bearings are lubricated by one-shot application of gun at either end of idler.

Same manufacturer has developed a "belt trainer" to maintain alignment of conveyor belts, both carrying and return. The training is accomplished by means of a roller-bearing troughing idler mounted on a swivel or bell crank which carries a brake shoe on its other end. When the edge of the belt touches the idler even lightly the brake drags on the underside of the end pulley of the idler, causing a slight drag and swinging the idler to steer the belt back to its central position. Rubber-covered pulleys are provided if abrasive material is to be handled.

One concern that makes roller conveyors uses hexagonal rollers instead of round shafts to prevent wearing motion between shaft and frame and shaft and inner race, also a flexible radial switch for transferring from one line to several lines or *vice versa*. Frames and supports are of all-welded construction.

Two additional methods of transmitting power to live rollers have been devised—one by contact with smooth-top flexible chain, wherein rollers float over chain and additional pressure of commodity causes rollers to be actuated by chain; the other by belt that travels over a sheet-metal bed instead of conventional roller idlers—said to reduce power consumption by eliminating flexing of transmission belt.

Of major importance in another

line of gravity and power-driven roller conveyors is improvement in design of bearings, including better protection against extraneous matter; a means of locking inner race to axle of rollers; heat-resisting bearings; heavy-duty series of rollers with continuous capacity of 8,000 pounds.

Two light-duty package handling belt conveyors in same line permit location of driving mechanism at any point along intermediate section of conveyor and underneath conveyor within outer limits of conveyor frame. No take-ups required.

Brand-new with this concern are two automatic dispatching methods that use photo-electric cells to provide the selective means—one by color variations, the other by varying electric impulses.

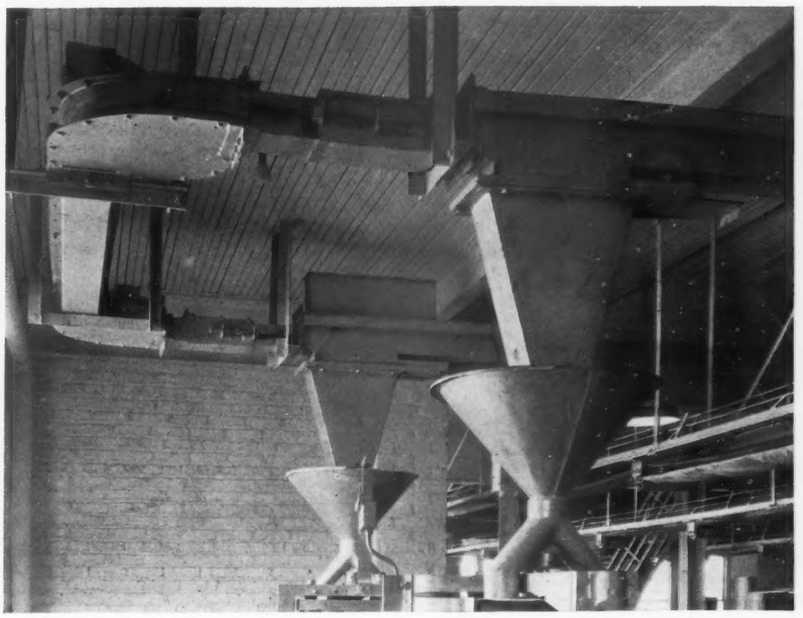
Routing of packages by the first method is determined by color and position of stickers, the side to have the sticker depending upon whether the branch-line conveyor is located to the left or right of the distributing conveyor.

With the second system the latching of deflectors operates not by a single current impulse produced by a marker or sticker of selected color, but by a series of impulses produced by a series of similarly colored markers or a series of spots of the same color on a single marker. For example, a system may include five deflecting stations, first operated by five impulses, second by four impulses, and so on.

Selective dispatching systems like these are adaptable to any condition where packages are received from any number of buildings or units and are delivered to different floors or bays in a warehouse.

Special development in one line of chain conveyors is a "pitching roll" conveyor. Instead of letting barrels stand while surplus pitch drains off, they are rolled as they travel slowly down conveyor. Pitch is thus distributed uniformly.

Still another manufacturer introduces the compensating trolley hanger to replace the non-compensating type; a flangeless ball-bearing trolley roller adjustable for wear; idler units of welded sheet steel; and a universal boot applicable to any type of elevator, that provides for greater flexibility in feed spout location and control of pit depth.



Flexibility of arrangement, cleanliness of handling, are two important advantages of the Redler-type skeleton flight conveyor that moves salt from storage to packaging machines at Morton Salt Company, Port Huron, Michigan

Another manufacturer points out availablity of chain conveying equipment for operation in temperatures up to 700 degrees Fahrenheit.

An aluminum portable belt conveyor has been introduced by one equipment maker.

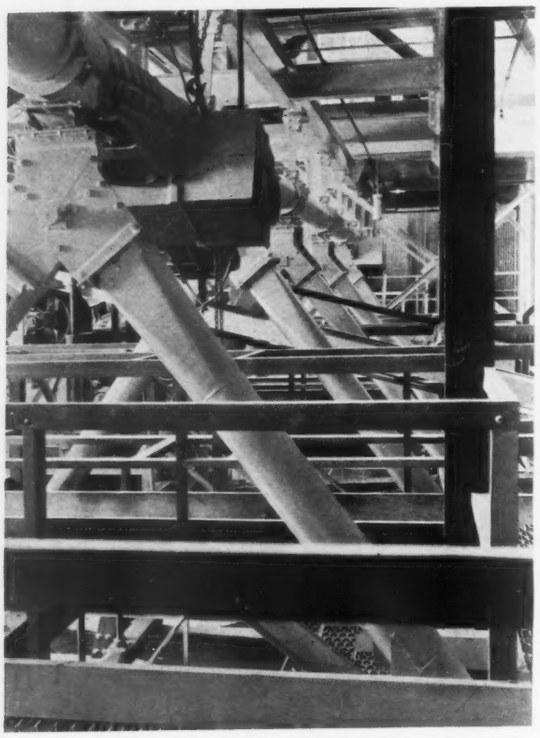
Important among conveying developments are the electric vibrating equipments originally designed for metals and coal conveying, now used in other industries to screen, feed, convey, cool, dry and pack bulk materials. Control covers a wide operating range. For example, a small feeder handling 2,000 pounds per hour can be slowed down to handle an ounce or two. Feeders are built to handle up to 1,000 tons per hour. Material can be conveyed in pipes for considerable distances — even on slightly ascending slopes. Power consumption is low. So is maintenance cost, because of the absence of moving parts.

Developments in bulk handling equipment include screw conveyors designed to move materials vertically and the "en masse" skeleton flight conveyors of the Redler type. Flights are H- or U-shaped. Moving element is flexible, can carry load horizontally or vertically, around corners if necessary. Material being moved is at rest in relation to moving element.

Design of one type of equipment is based upon the characteristic of dry, pulverized materials to behave substantially as liquids when aerated. The pump as now improved permits operation on about a half or a third of the air pressure previously used. Resulting power saving is said to range from 35 to 45 per cent. Impeller screw and housing have been redesigned as a unit with integral oil reservoir for constant-rate lubrication of bearings. Automatic check valve supplements effect of decreased pitch of screw when handling low loads. Valve is inoperative when pump operates at full capacity.

Overhead Carriers

One manufacturer has introduced a pneumatic tire with tube into the power unit. Latter consists of electric motor and reducer, driving a balloon tire mounted to give traction through pressure against under-surface of rail. It is claimed that high coefficient of friction between tire and steel rail gives non-slipping grip; permits ¾-hp. motor to move



Electric vibrating conveyor, originally designed to move metals and coal, here feeds a dusty, poisonous chemical to storage bins

train of trolleys or racks carrying combined load of 10 tons along horizontal runways; serves efficiently in moving loads up and down heavy grades.

A second concern has added a line of track switches and related mechanism in order to make its equipment available in 2-ton, as well as 1- and 3-ton capacites.

Another manufacturer now uses trolley wheels with crowned treads, approximating a sphere in shape, to move hammering or peening action of wheels farther from edge of rail and to reduce area of contact of wheel with rail.

Mobile Carriers

Major improvements in one line of floor trucks include semi-steel castings, rubber-tired wheels, roller bearings in all wheels, grease-gun lubrication.

Another manufacturer has brought out an improved type of pressed steel wheel, also offers rubber tires, roller bearings. Added to this line are hand trucks, specially designed to handle beer kegs, drums, cement and lime in paper bags, oblong cases; and such handling accessories as pressed steel barrel cradles, one-man carboy tilters.

Third concern has added spring-bearing trucks with rubber-tired wheels, claims springs absorb most of shocks, add to wheel life.

Close grouping of machines and narrowing of aisles have, according to one manufacturer, brought about a demand for casters that will swivel more easily and permit sharper turns. Hence a line of double ball-race swivel casters. Wheels are farther off center. Extra wear is taken care of by additional row of bearings close to king bolt.

Rubber-tired wheels have increased in popularity. One concern offers soft rubber tires for use on irregular floors, semi-hard for comparatively smooth floors where heavy overloads must be carried.

Great advances have been made to improve efficiency, appearance, and load-carrying ability of industrial trucks and tractors, and to lower maintenance costs.

Important recent development is use of pallets with tiering-fork trucks. Pallets are inexpensive, can be carried and stacked in much the same manner as skids with high-lift platform trucks. Some classes of material—baled pulp, tin plate, for example—can be picked up, transported, and stacked directly without pallets or skids.

Fork trucks are usually of tilting type. Uprights tilt back 15 to 20 degrees, which cradles load against back of fork carriage to prevent slipping and also to bring load back nearer to center of gravity of truck. Telescoping models permit stacking clear to warehouse roof, are low enough telescoped to enter car doors.

Special types fit unusual operating conditions, handle special classes of material such as rolls of paper or coils of strip steel.

Examination of one manufacturer's 3-ton elevating platform truck shows welded lower frame and platform, controller that eliminates plugging of travel motor, anti-friction bearings in steering mechanism.

Another manufacturer has added power steer, shockless steering, magnetic controller operation, single-reduction spur-gear drive said to afford higher speed with minimum current consumption, solid steel construction, operator's safety guard, quarter-elliptic spring suspension supporting gravity load only, torque mounting on drive axle comparable to floating power suspension.

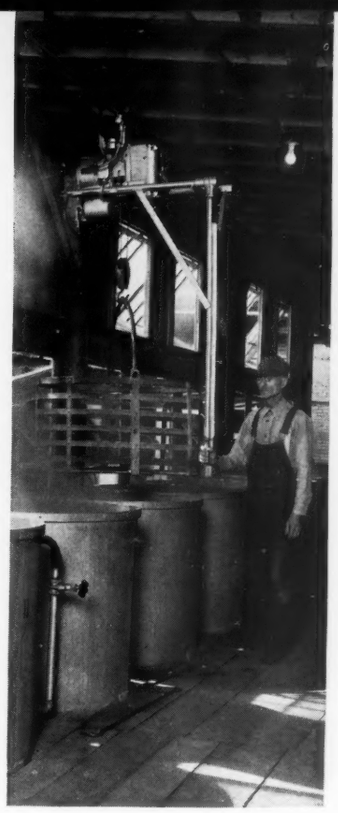
In one line of tractors frames are welded; metal universal joints are used in place of fabric disk. To simplify service, the same concern has adopted for all locations the largest ball bearing required in the transmission.

Still another manufacturer offers low-lift, high-lift, and telescoping high-lift trucks in capacities up to 10,000 pounds. Hydraulic hoist system requires no power when lowering, eliminates need for worm gearing or brakes to control lowering speed. Magnetic contactor control makes it impossible to apply full power instantly, eliminates arcing, minimizes maintenance costs. Brakes located within drive wheels are said to provide smoother action, reduce stress and wear on drive joints, splines, gears, bearings, and motor shaft. Wheels are provided with ball-bearing steering knuckles and adjustable thrust-bearing caps, removing excessive clearing and shock loading of bearings when traveling over rough runways.

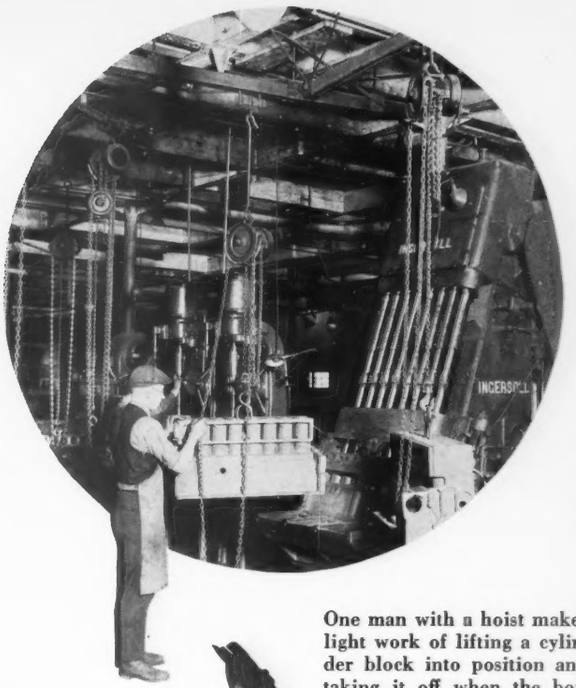
Same manufacturer has introduced a small gasoline-powered tractor with full-spring suspension and internal brakes located in drive wheels. This concern equips trailers with flat-top self-coupler jaw end which can be easily operated despite overhanging loads and is released by light foot pressure.

A Tool of Management

From these and countless other items of technological improvement, it is plain that modern handling equipment may be made a sharp-edged cost-cutting tool of production management.

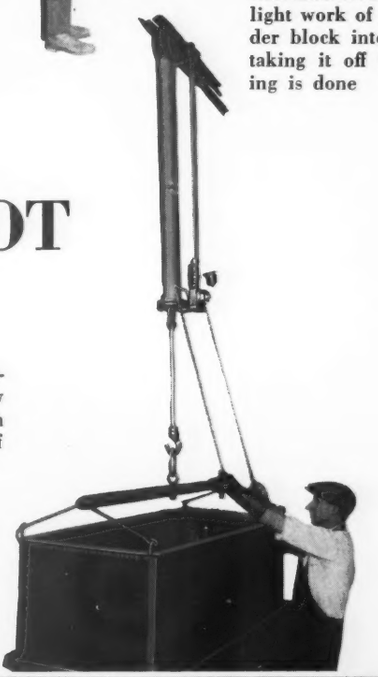


Outrig control provides safe and rapid handling, keeps operator in the clear, enables him to hoist, lower, and push the load all with the same handle



One man with a hoist makes light work of lifting a cylinder block into position and taking it off when the boring is done

HOISTS ON THE SPOT



Pneumatic hoist at the Gottfried Baking Company, New York, lifts racks loaded with cake pans in and out of cleaning and rinsing vats

One man with 2-ton crane and electric hoist handles entire manufacture of ice at the West Michigan Dock and Market Corporation's ice plant, Muskegon, Michigan

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Nine electric hoists, outrig controlled, handle baskets of cans in and out of retorts at the Campbell Soup Company's plant, Chicago

EN ROUTE ON CONVEYORS

Underneath the track hopper at Bakelite Corporation, Bound Brook, N. J., a reciprocating feeder delivers coal to a crusher. Crushed coal is delivered by belt and bucket elevator to ground storage or by inclined belt to a 200-ton bunker inside the boiler house. Ashes are carried by rocker dump car to the bucket of a skip hoist, which dumps into the elevated bin in the foreground

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By rolling beer barrels at just the right speed as they are chain conveyed from pitching machine to filling stations or storage, the still plastic pitch is evenly distributed, has cooled and hardened by the time the barrels arrive at the other end of the line

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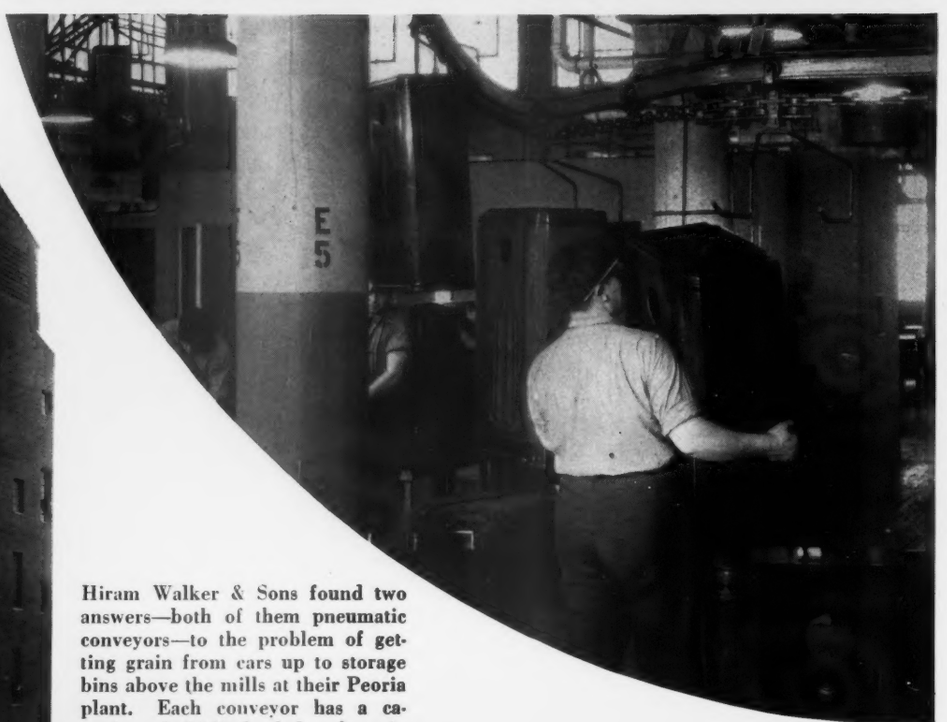
Overhead chain conveyors are no better than their fixtures. The hooks on this conveyor at Stewart-Warner Corporation, Chicago, are built for the particular task of moving radio cabinets. Note how the conveyor, meeting the obstacle of men at work, rises to the emergency



Hiram Walker & Sons found two answers—both of them pneumatic conveyors—to the problem of getting grain from cars up to storage bins above the mills at their Peoria plant. Each conveyor has a capacity of 2,000 bushels of grain an hour

Where changes of level are required, an electrically operated and controlled pusher bar conveyor does the necessary elevating. Installation at McKesson Western Wholesale Drug, Los Angeles

Dry ice gets our vote for the product we should not like to handle manually. This conveyor, at the Publicker Commercial Alcohol Company's plant in Philadelphia, handles it every day, has power-driven wood rollers. Cakes are sawed on the move

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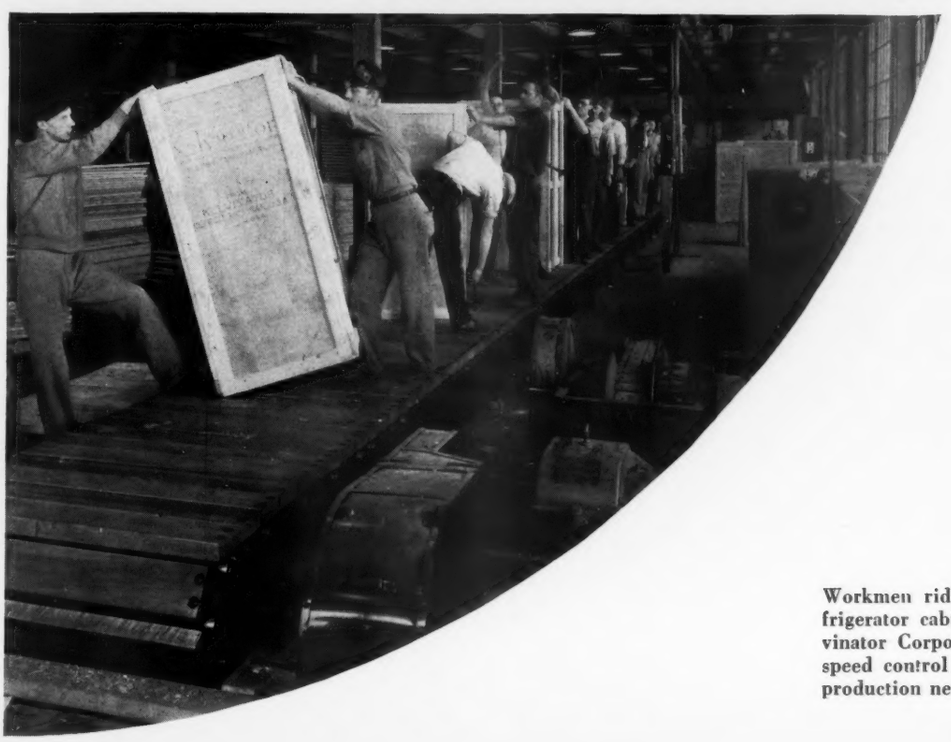

Bottled gin—at Century Distilling Company, Peoria—moves via belt line from filling and labeling to wrapping. Return belt carries packages back to roller tables where they are packed in cartons that arrive by chute from upstairs. Roller conveyors carry filled cartons to a belt booster which elevates them to another gravity roller conveyor. It takes them through sealing machines and on to shipping room or storage

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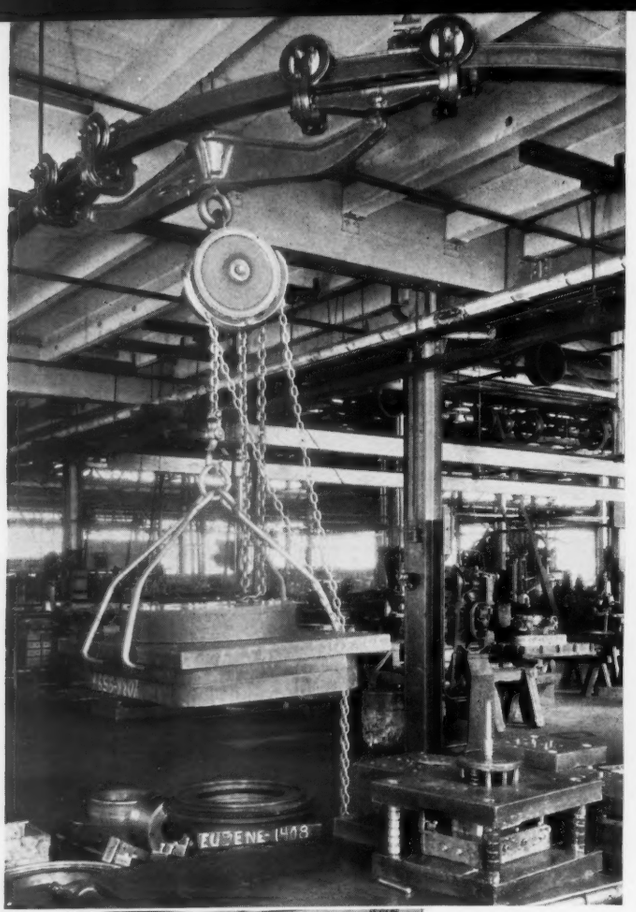
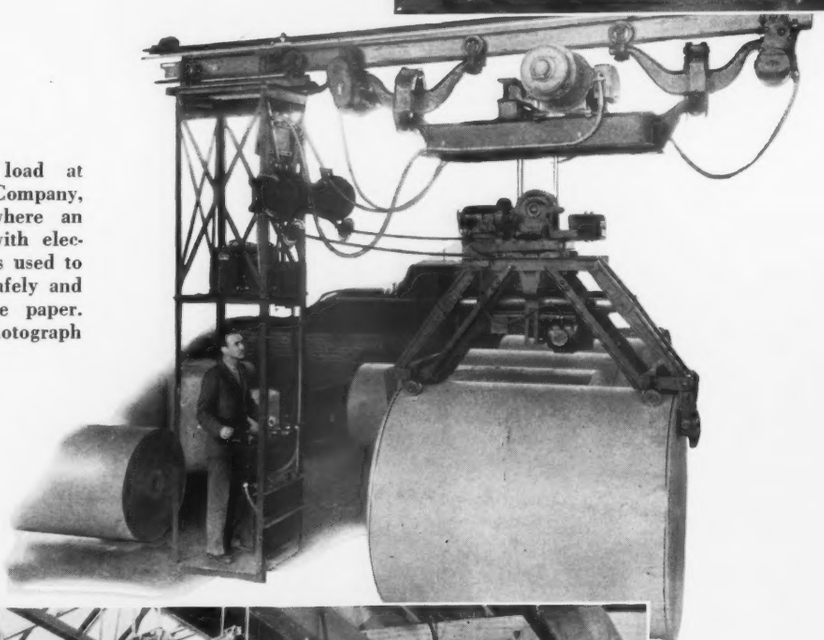
Workmen ride the platform conveyor on which refrigerator cabinets are assembled and crated at Kelvinator Corporation's Grand Rapids plant. Variable speed control tailors the rate of travel to fit varying production needs

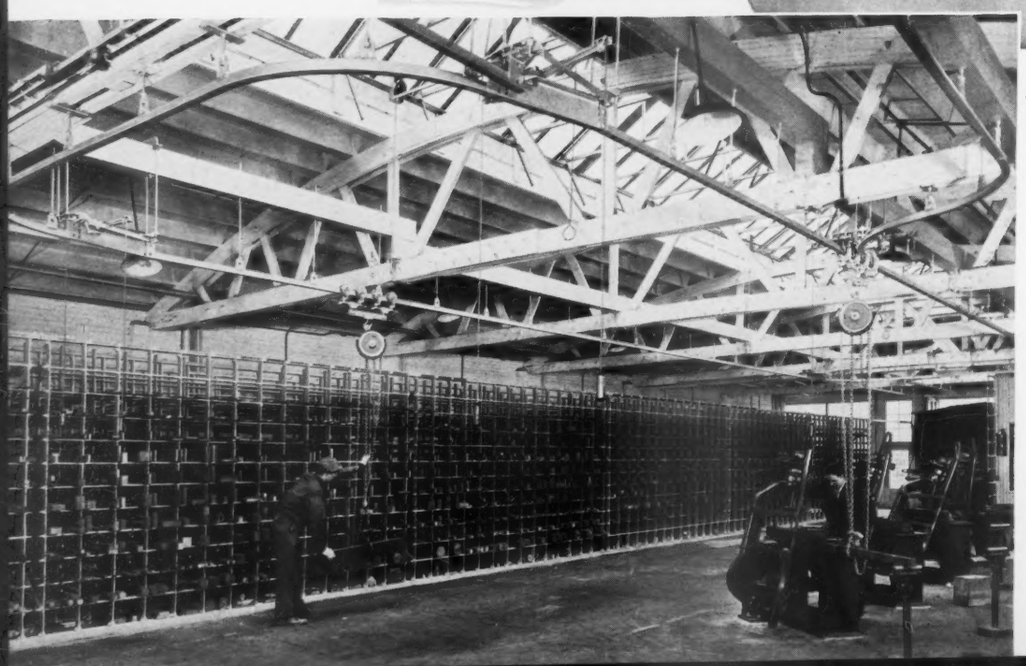
Riding the Overhead Rails



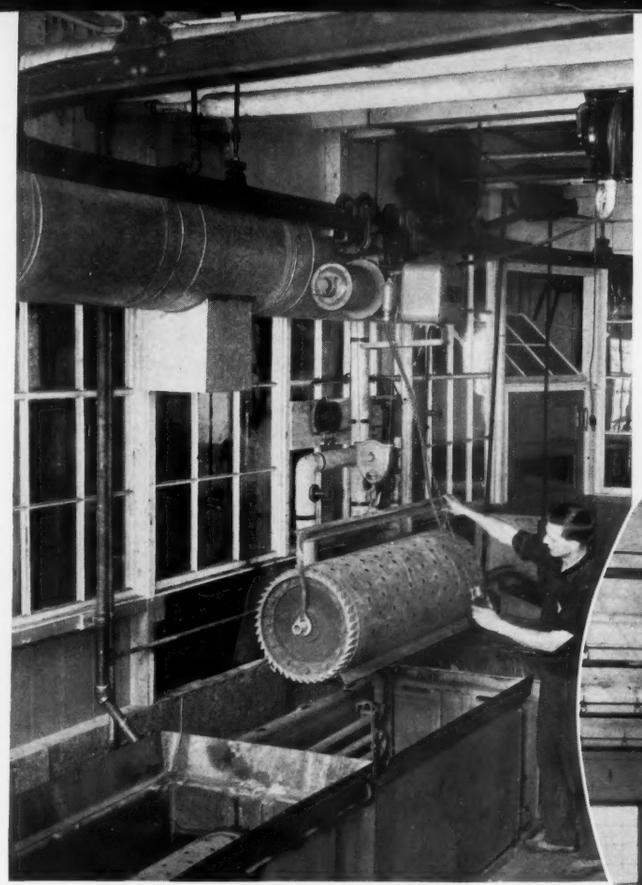
Moving heavy dies from storage to presses and back again constitutes a serious problem in many a plant. Geometric Stamping Company, Cleveland, uses a 3-ton hand-operated tramrail system



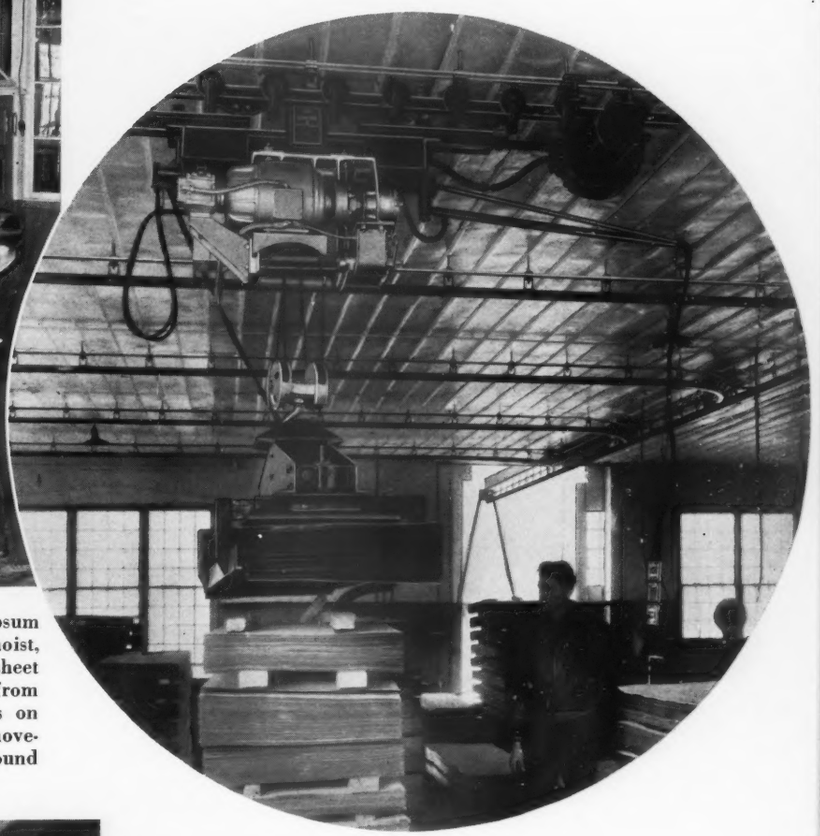
Operator rides with load at Owens Illinois Glass Company, Charleston, W. Va., where an overhead rail system with electric hoist and grapple is used to handle rolls of paper safely and without damage to the paper. The roll in the photograph weighs 4,200 pounds



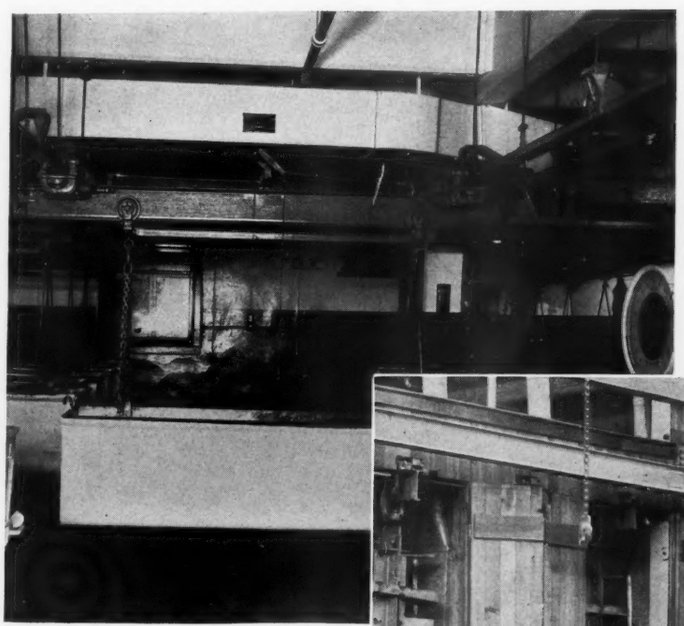
Monorail at Columbia Tool Steel Company, Chicago, handles steel to storage racks, from storage to saws, and thence to delivery trucks



Without the tramrail, dipping spectacle cases into cleaning and rinsing baths at American Optical Company, Southbridge, Mass., would no longer be a rapid, safe, one-man job



Complete overhead carrier at National Gypsum Company, Niles, Ohio, consisting of electric hoist, pneumatic-tired tractor, and electrified steel sheet grab, brings sheets from cars to storage and from storage to processing machines. Pushbuttons on swinging arm control vertical and horizontal movements of loads, allow operator to pass around three sides of load



Traveling transfer rail and complete tramrail installations facilitate handling, make every foot of storage space available in the fermentation room at Williams Bakery, Wilkes-Barre, Pa. The same rail system with pushbutton elevator takes troughs and "sponges" back to the weigh-off room and mixing machine on the floor above

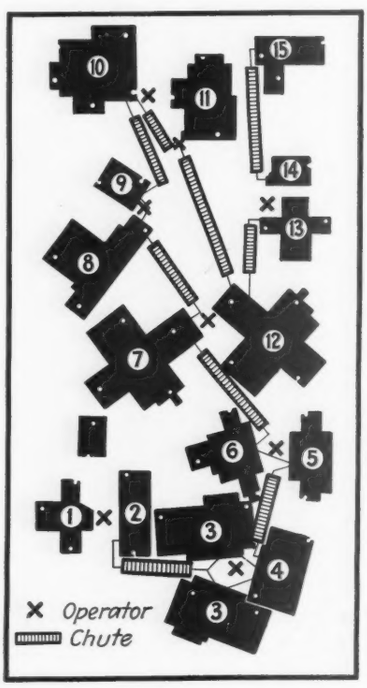
In a pottery. Transfer crane connects monorail system with overhead tracks that carry loads through drying ovens at Hall China Company, East Liverpool, Ohio

Correct Plant Layout Minimizes Travel of Products, Parts, and People

DOES YOUR plant look like a picture out of *The Engineering Magazine* for September, 1893? Or have you watched and profited by the pronounced trend toward motion-economized layout that has been publicized in recent issues of *Factory?*

Customary procedure has always been to lay out equipment in straight lines with good, wide aisles. The aisles made convenient storage spaces for work in process, and—when mechanical handling began to enter the picture—excellent runways for conveyors and industrial trucks.

So far, so good—until the motion economy experts began to take note of the fact that oftentimes an operator had to make a complete about-face, walk several steps, get or get rid of stock, and then walk back to his machine.



Enough of a Cadillac layout to give a rough idea of what motion study had done to it

To point out unnecessary steps to the motion economy man is to wave the proverbial red flag before the aggravated bull at the Spanish fiesta. First intimation that someone was taking a healthy poke at accepted practice, that something big was happening to plant layout, came in a late 1931 article describing recent developments at Cadillac.

First, they had taken a connecting rod line of twelve machines, six on either side of a roller conveyor, with a man to each machine, and completely rearranged it. The conveyor stayed right where it was, but the machines were moved around so that one man could run two perfectly well. Walking time was completely eliminated, idle time utilized.

All of which was nothing to what they did to a department machining a piece that weighed 16 pounds.

Things really happened there to layout. Straight lines, wide aisles—those convenient catch-alls for work that seemed to sit around till someone got good and ready to move it—were done away with forever. The new layout looked somewhat as if the man who did the job had stood a dozen feet away from the drawing board and tossed templets at it with a silent prayer that they might stick.

Enough of the new layout is shown to give you a rough idea. The old department had been laid out in the usual fashion—machines lined up parallel to walls. Parts were moved in wheeled containers.

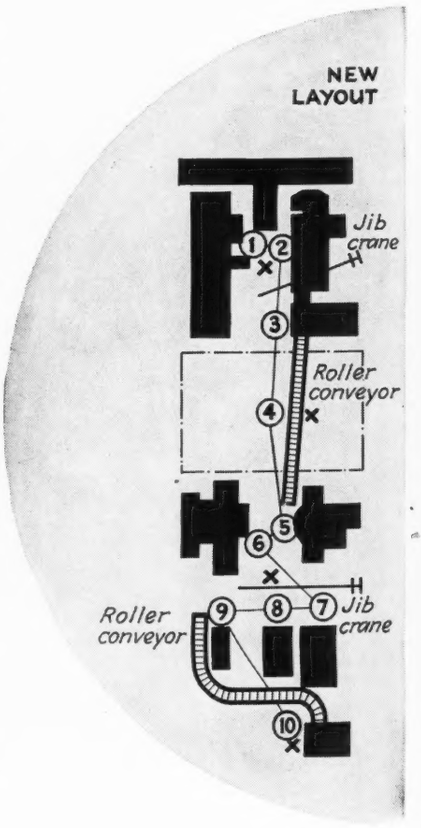
In the new department, parts were chuted between machines. Seventeen men did the work of 27. Several machines were eliminated. Floor space was reduced 40 per cent. Amount of work in process was substantially lowered.

Things *were* happening to layout all right. Another typical example is found in a motor-frame machining group at Westinghouse. Both old and new layouts are reproduced here. Note, in the conventional straight-line layout, the distance traveled, much of it backtracking. Note that 10 operators ran 10 machines.

Now the new layout. Same machines. Same operations. Note how handling has very definitely made its contribution. Three sections of roller conveyor. Two jib cranes with electric hoists, one serving the group of machines at the left of the welding booth, the other the group at the right. Observe how 10 men became only four.

Out of these and similar experiences, motion economy experts have set up what amounts to a technique in making plant layouts.

First, they determine whether present layout is satisfactory. Tool used, the process flow chart. It shows, for instance, that there are 59 steps in the manufacture of a tiny



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See What Motion Study Did to Plant Layout . December, 1931
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What's Happening to Plant Layout? . . . . . May, 1933
A. H. Mogensen

Latest in Layouts Did This to Costs . . . . . February, 1934
R. H. Patchen

Layout Cashes In on Motion Economy . . . . . March, 1934
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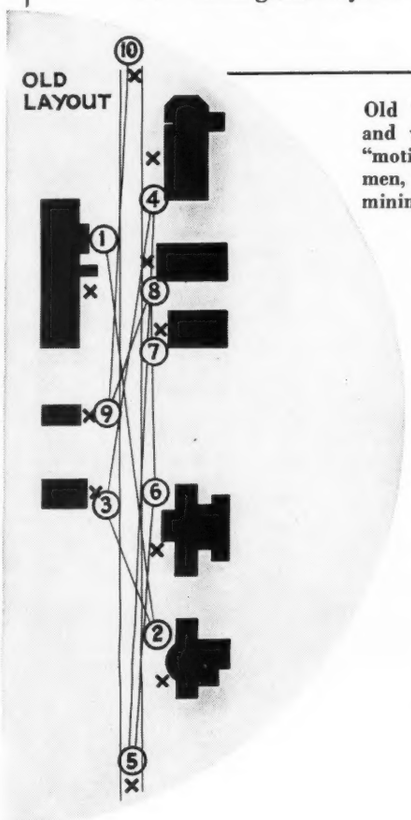
New Equipment, New Layout . . . . . July, 1934
Ray Rindfleisch

Right Layout Scores Again . . . . . February, 1935
F. E. Wikander

and

Motion-Economized Layout
A. H. Mogensen

I. Now Look at Layout . . . . . December, 1934
II. From 59 Steps to 22 . . . . . January, 1935
III. Next, the Templet Layout . . . . . February, 1935
IV. Selling the Layout . . . . . March, 1935



Old "straight-line" layout with ten men and wide aisle for lots of travel. New "motion-economized" layout with four men, three conveyors, two jib cranes, and minimum travel

coil spring you happen to be making, that said tiny spring travels a total distance of 4,041 feet.

Second, they analyze the operation, find that your little coil spring, say, has been traveling too far by 3,756 feet, that steps in manufacture may really be cut from 59 to 22.

Nothing to do now but make a templet layout and sell it to the management — sometimes the hardest step of all.

Which leaves the actual laying out to be done. Throughout the entire process the emphasis has been on the need for flexibility of operation and for cutting down the travel of products, parts, and persons. Here, of course, modern handling definitely enters the picture, makes its contribution. We find it used correctly, even sparingly, in the motion-economized layout. Just enough handling equipment and no more is the order of the day. Any motion economy man will tell you that today's big job is to enable the operator to do more of the *do*, less of the *make ready* and the *put away*. Modern handling equipment can materially contribute toward this end.

The task often resolves itself into a simple problem of getting material to the machines fast enough, taking it away again—as in modern cigarette manufacture where machine speeds have been doubled and redoubled in recent years.

More space, wider aisles? No. Chutes, of course, to get the tobacco to the job. An overhead chain conveyor to take away the cigarettes.

Effective layout may also involve the change-over from functional to straight-line operation—as in the manufacture of sequence switches at Western Electric Company.

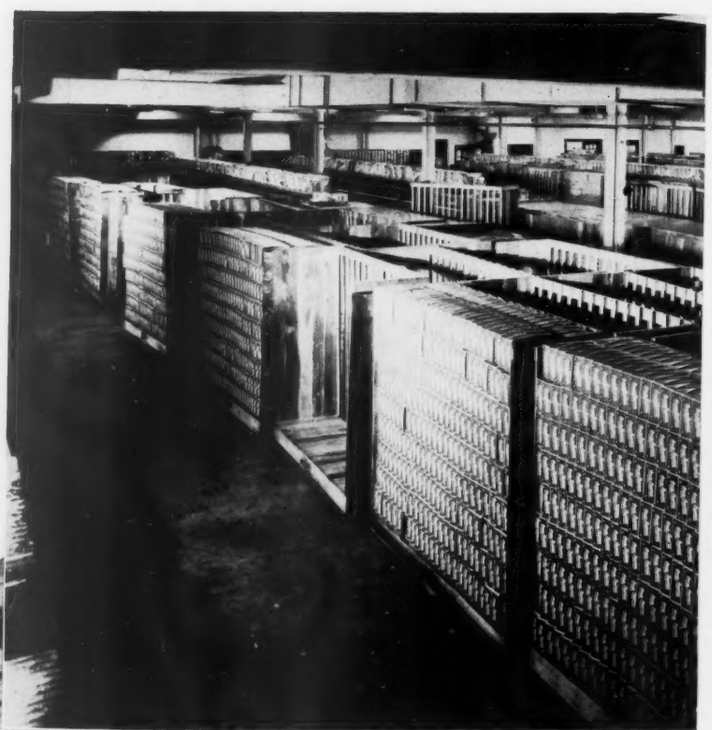
Here, a live-roll conveyor encircles the department. Double-decked spurs serve groups of machines and assembly benches, the lower deck for incoming, the upper for outgoing work. Tote pans of piece parts can be put on at any spur and keyed for automatic deflection at the spur adjacent to which the next operation is to be performed.

Flexibility is a striking advantage of this type of installation. Equipment involved in making a complete part is readily arranged in groups, so that parts may be moved from machine to machine by chute or conveyor and so that full advantage may be taken of whatever may be the most economical type of drive for a given condition. Grouping by operation is thus attained with none of the disadvantages apparent in functional manufacture.

Chief advantage, of course, is that the conveyor becomes in a real sense a traveling storeroom of parts ready for immediate delivery wherever and whenever required. Results in this case included 50 to 70 per cent reductions in raw-material, process-stock, and piece-part investments, a 17 per cent saving in floor space, and approximately 85 per cent in manufacturing interval.

On Trackless Trails

Empty space up around the ceiling costs money, is effectively turned into useful storage room by the tiering fork truck-pallet team. Twelve crates make a convenient unit load in the warehouse pictured. Crates are filled with bottles

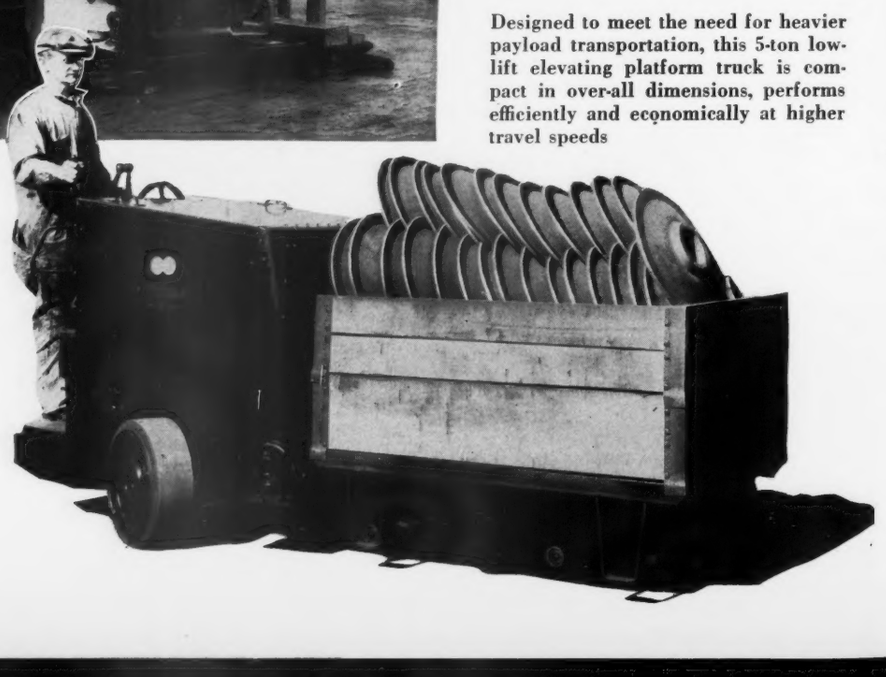


Three-sided superstructure floor trucks handled filled and empty cartons through manufacturing, storage, and shipping operations at Mars Candy Company, Chicago. Four-wheeled, balance-type running gear enables truck to turn in its own length

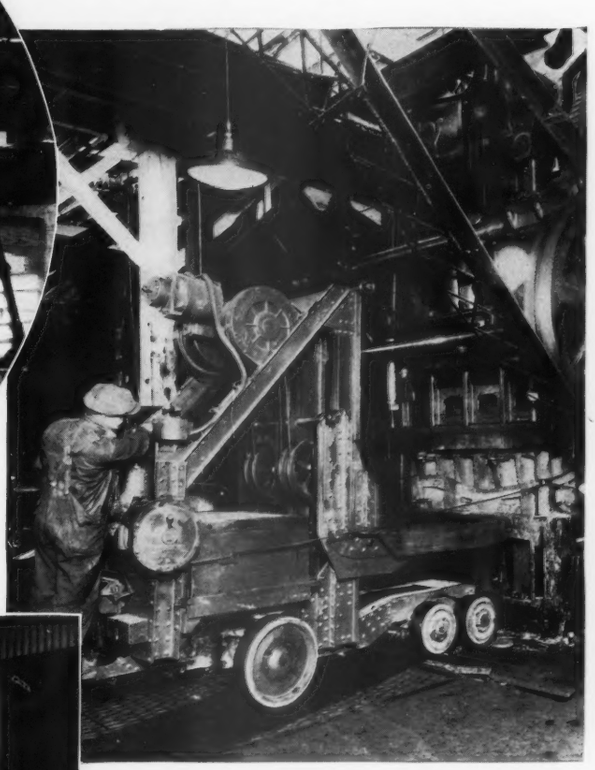
•

Designed to meet the need for heavier payload transportation, this 5-ton low-lift elevating platform truck is compact in over-all dimensions, performs efficiently and economically at higher travel speeds

Horsepower substitutes for manpower in such jobs as moving 5-ton machines. And in these days of changing layouts, machines must often be moved. This tractor had been on the job eight years when this photograph was taken



Hand lift truck—with skid, of course—used to handle tiles in a ceramic plant



Die-handling high-lift trucks are made in capacities up to 25 tons. This one, at Motors Metal Manufacturing Company, Detroit, speeds up changes of dies, reduces idle press time, eliminates accidents to personnel

One man, one bag of sugar. One tractor, 125 bags. Add trailers as needed. Another plant finds a recipe for the economical handling that carries low manufacturing costs in its train

•

Assembly lines must not wait. Tractors and trailers provide fast, flexible transportation. This tractor works in the heat-treatment department of an automotive concern. Note carriers specially designed to handle the product

•

Pushing and pulling tractor with 6-cylinder motor handles materials from one department to another on trailers. Lights for night operation in yards. Turns in 108-in. radius, has drawbar pull of 2,450 pounds, weighs 2,430, will go 18 miles an hour if you want it to

As a Guide to Selecting Your Equipment—a Materials Handling Check Chart

ANY ATTEMPT to select handling equipment on a purely scientific basis must recognize the fact that mechanical handling, after all, is still an *art*, not a *science*. Certainly no hard and fast rules can be applied. Certainly the human factor enters to a large extent. Certainly laboratory methods cannot for the most part be employed.

It is with this brief introductory background that *Factory* offers the following *Materials Handling Check Chart* as a guide to the selection of equipment.

This Check Chart—reproduced in two parts—is not a magic formula that gives a mechanical answer, thereby replacing individual thinking and personal judgment. It is merely a guide to such thinking. It may serve, if in no other capacity, as an orderly arrangement of your own observations and as a guaranty that you have not overlooked any factor influencing the ultimate decision.

In many instances the chart may not be necessary. Many materials handling problems have only one solution—and that one solution is apparent at first glance.

When It's Hard to Choose

Other problems, however, resolve themselves into a choice between two or more types of handling equipment. And there's where the fun begins.

It is for this type of problem that the check chart is useful.

Part I of the Chart is constructed on the principle that materials handling is far from being merely a problem of getting things from *here* to *there*, that certain physical factors govern the preliminary choice of equipment, that careful consideration of these factors will narrow down the field to a choice between two, say, or possibly three types of equipment.

From that point on, the problem becomes nothing but one of getting comparative costs. Part II of the Check Chart makes it possible to obtain the costs with the assurance that every factor with a direct bearing on the final result will get a hearing.

To assist the reader who wishes to make his own survey, a typical case study has been worked out. Figures in every instance are hypothetical, and to insure that no one shall draw false conclusions as to the general superiority of one type of equipment over another, final figures have purposely been made to come out even.

Complicated? No. To follow the Check Chart method from start to finish is merely to insure yourself against the pardonable omission of one or more of the physical or economic factors that influence final decision.

Formulas? None. No higher mathematics needed.

Time-consuming? Well, yes. But isn't it worth a few hours of your time to use this orderly method of checking your plans to install equipment that may easily run into thousands of dollars?

Materials Handling Bibliography

A Selected List of *Factory* Articles

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Millions for Equipment ..... **May, 1935**
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Twice the Storage ..... **April, 1935**
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All by Himself ..... **July, 1934**

Cost, Health, and Safety Said "Conveyorize" .... **June, 1934**
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Couldn't Raise Prices So Went After Costs ..... **April, 1934**
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Red Ink or Black? ..... **October, 1933**
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Well Handled Is Well Processed ..... **October, 1933**

New Equipment, New Products That Sell ..... **August, 1933**
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One Plant to Do the Work of Two ..... **May, 1933**
W. C. HIPPLE

See Also
Layout Articles Listed on Page S73

MATERIALS HANDLING CHECK CHART

Part I. Physical Factors Affecting Preliminary Choice of E

KEY

Checks (√) indicate equipment may ordinarily be used

Bars (—) indicate equipment will not ordinarily be used

Blanks indicate that reader when making his own study must check (√) or bar (—) equipment according to specific conditions

	Type of Material					Nature of Material		Amount of Material						Frequency of Movement			Dire and Le Move
			Unit					Minimum		Average		Maximum					
	Liquid (not in containers)	Bulk	Small	Medium	Large	Fragile	Sturdy	Tons per Hour	Units per Hour	Tons per Hour	Units per Hour	Tons per Hour	Units per Hour	Continuous	Intermittent	Occasional	Horizontal
Data (filled in here for hypothetical case-see text at right of chart)				√			√	5				40			√		40 to 400 ft.
Cranes																	
Overhead Traveling	—	√	—	√	√	√	√							—	√	√	√
Gantry and Bridge	—	√	—	√	√	√	√							—	√	√	√
Jib and Pillar	—	√	√	√	√	√	√							—	√	√	—
Locomotive, Mobile, Portable	—	√	—	√	√	√	√							—	√	√	√
Derrick	—	√	—	√	√	√	√							—	√	√	—
Overhead Carriers																	
Monorail, Tramrail	—	√	√	√	√	√	√							√	√	—	√
Telpher	—	√	—	—	√	√	√							√	√	—	√
Cableway	—	√	—	—	√	√	√							√	√	—	√
Hoists (Stationary)																	
Chain	—	—	—	√	√	√	√							—	—	√	—
Electric	—	—	—	√	√	√	√							—	—	√	—
Pneumatic	—	—	—	√	√	√	√							—	—	√	—
Conveyors																	
Chutes	—	√	√	√	√	√	√							√	√	√	√
Roller	—	—	√	√	√	√	√							√	√	—	√
Push-Bar	—	—	√	√	√	√	√							√	√	—	√
Apron	—	√	√	√	√	—	√							√	√	—	√
Chain	—	—	√	√	√	√	√							√	√	—	√
Belt	—	√	√	√	—	√	√							√	√	—	√
Slat	—	—	√	√	√	√	√							√	√	—	√
Bucket Elevator	—	√	√	—	—	—	√							√	√	—	—
Screw	—	√	—	—	—	—	√							√	√	—	√
Flight (including Redler type)	—	√	√	—	—	—	√							√	√	—	√
Pneumatic	—	√	√	√	—	—	√							√	√	—	√
Portable	—	√	√	√	—	√	√							—	√	√	√
Mobile and Portable Carriers																	
Trucks (Hand and Floor)	—	√	√	√	—	√	√							—	√	√	√
Trailers	—	√	√	√	√	√	√							—	√	√	√
Tractors	—	√	√	√	√	√	√							—	√	√	√
Platform Trucks	—	√	√	√	√	√	√							—	√	√	√
Lift Trucks	—	√	√	√	√	√	√							—	√	√	√
Tiering Trucks	—	—	√	√	√	√	√							—	√	√	√
Industrial Cars	—	√	√	√	√	√	√							—	√	√	√
Locomotives	—	√	√	√	√	√	√							—	√	√	√
Elevators, Portable	—	√	√	√	√	√	√							—	√	√	—
Tiering Machines	—	—	√	√	√	√	√							—	√	√	—

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July, 1935

ART
Choice of Equipment

cy nt	Direction and Length of Movement		Will Obstructions Prevent Use?	Production Operations Affecting Materials Handling					
Occasional	Horizontal	Vertical		Processed in Transit	Inspected in Transit	Stored in Transit	Weighed in Transit	Nature of Loading Operation	Nature of Unloading Operation
	40 to 400 ft.	√	Door						Piled
√	√	√		—	—	—	√		
√	√	√		—	—	—	√		
√	—	√		—	—	—	—		
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√	—	√		—	—	—	—		
√	—	√		—	—	—	—		

NOTES

Purpose of chart is to indicate whether equipment may *ordinarily* be used or will *not ordinarily* be selected to fit a given condition.

Liquids: Suitably contained, may of course be handled in practically any type of equipment; in liquid form, are usually piped and pumped.

Bulk: Proper containers or grabs are implied with equipment checked as suitable yet not designed specifically for bulk handling.

Small, Medium, Large: Use judgment. An overhead crane *can* handle small units. But if you had only small units, would you *ordinarily* select a crane? Large may mean either mass or volume.

Fragile, Sturdy: Fragile materials, suitably contained, may be classified as sturdy, hence handled by practically any type of equipment.

Horizontal, Vertical: (1) Movement of materials is often a combination of both. Example, tiering trucks. (2) Or it may include vertical movement when primary purpose is to move horizontally. Example, tramrails. (3) Jib crane, primarily for vertical, may be used for horizontal movement within limits.

Process, Inspect in Transit: Possible on some types here barred. Again, the point is: If you had a certain operation to perform in transit, would you *ordinarily* choose that equipment?

Store in Transit: See above. For example, materials are in rare instances stored on slat conveyors. Ordinarily, need to store would bar that equipment.

Weigh in Transit: Possible, seldom practicable, on some types here barred.

Case Study—I

Problem: To move case goods from cars to warehouse.

Filling in the data column we note:

1. Medium-sized units.
2. Material is sturdy.
3. Must move 5 to 40 tons per hour.
4. Movement is intermittent.
5. Distances vary, 40 to 400 feet.
6. Vertical movement only in storing.
7. Only obstruction is a doorway.
8. No operations in transit.
9. Material is piled at destination.

Next determine which equipment is checked (√) and may ordinarily be used, which equipment is barred (—) and will *not ordinarily* be used. Knowledge of specific conditions determines whether to bar or check blank spaces.

Let us say for sake of illustration that preliminary choice narrows down to electric trucks or tramrail. Consultation with equipment manufacturers indicates following needs:

Electric Trucks—2, fork-type, 2-ton, with charging equipment, 1,000 pallets. Investment, $8,000. Capacity, 60 tons per hour (2 trucks).

Tramrail—Cost, $4,500 plus $1,500 to install. Capacity, 75 tons per hour.

Turn to Part II for comparative costs. All figures are hypothetical.

Case Study—II

Part II continues our hypothetical case, shows how comparative cost figures are obtained. All figures serve merely to illustrate the method. Roman figures for trucks; italic for tramrail.

Computation of costs begins with labor. Two drivers are needed for the trucks. One man can operate the tramrail, but two more men are needed to pile material in the warehouse. To get unit labor costs for trucks and tramrail now becomes a matter of multiplying number of men by hourly rate, adding burden, and dividing by amount of material handled per hour.

Similarly, by following the method outlined in the chart, we get comparative costs for power, maintenance, depreciation, interest, insurance, taxes.

Comparative unit operating cost figures — remember, they are purely hypothetical—now look like this:

	Trucks	*Tramrail*
Labor	$0.0350	$0.0520
Power	0.0030	0.0015
Maintenance .	0.0130	0.0090
Operating Cost	$0.0510	$0.0625

Computing our hypothetical fixed charges we get the following:

	Trucks	*Tramrail*
Depreciation .	$1,500.00	$1,100.00
Interest	400.00	300.00
Insurance	120.00	90.00
Taxes	30.00	22.50
Fixed Charges	$2,050.00	$1.512.50

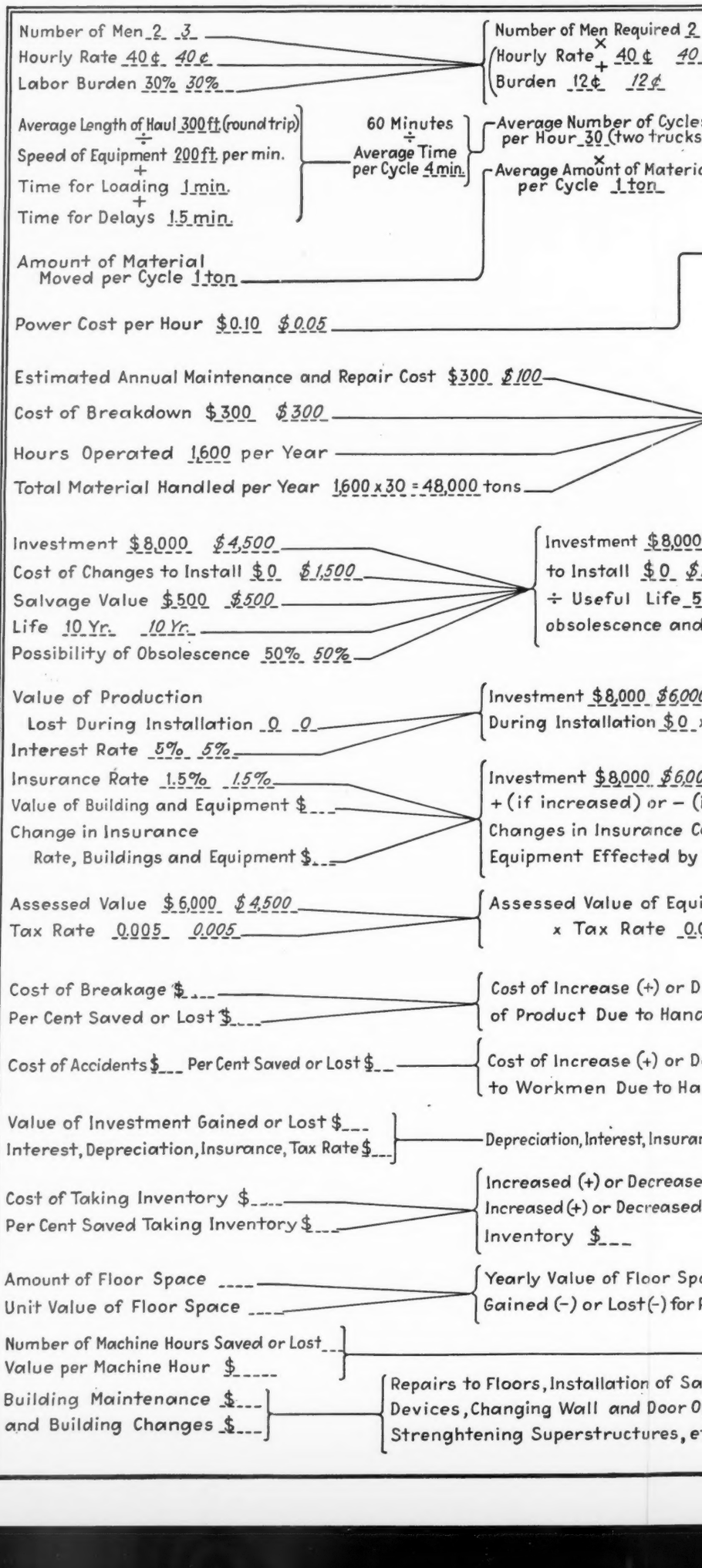
Dividing annual fixed charges by 48,000, the number of tons handled per year, we arrive at $0.043 and $0.0315 respectively as fixed charges per ton for trucks and tramrails.

Final figures now read as follows:

	Trucks	*Tramrail*
Operating ...	$0.0510	$0.0625
Fixed	0.0430	0.0315
Total	$0.0940	$0.0940

Unit costs are exactly the same! That *can* happen in a hypothetical case study. It would probably never happen in actual plant practice. If it does—and if the results at this stage do not point conclusively to one or another of the types of equipment being studied—the next step is to tackle the final section of Part II, which we have chosen to label "Indirect Charges."

No attempt has been made to carry the hypothetical case study through this stage to an ultimate conclusion because such factors as floor space, safety, breakage, inventories, etc., vary widely with conditions. Enough of the method has been indicated, however, so that the reader may determine how these indirect charges bear upon the problem. Upon that answer will depend the final selection of handling equipment.


Number of Men 2 3
Hourly Rate 40¢ 40¢
Labor Burden 30% 30%
Number of Men Required 2
Hourly Rate × 40¢ 40
Burden + 12¢ 12¢
Average Length of Haul 300 ft. (round trip)
÷
Speed of Equipment 200 ft. per min.
+
Time for Loading 1 min.
+
Time for Delays 1.5 min.
60 Minutes
÷
Average Time per Cycle 4 min.
Average Number of Cycles per Hour 30 (two trucks
×
Average Amount of Materia per Cycle 1 ton
Amount of Material Moved per Cycle 1 ton
Power Cost per Hour $0.10 $0.05
Estimated Annual Maintenance and Repair Cost $300 $100
Cost of Breakdown $300 $300
Hours Operated 1,600 per Year
Total Material Handled per Year 1,600 x 30 = 48,000 tons
Investment $8,000 $4,500
Cost of Changes to Install $0 $1,500
Salvage Value $500 $500
Life 10 Yr. 10 Yr.
Possibility of Obsolescence 50% 50%
Investment $8,000
to Install $0 $
÷ Useful Life 5
obsolescence and
Value of Production
Lost During Installation 0 0
Interest Rate 5% 5%
Investment $8,000 $6,000
During Installation $0
Insurance Rate 1.5% 1.5%
Value of Building and Equipment $
Change in Insurance
Rate, Buildings and Equipment $
Investment $8,000 $6,00
+ (if increased) or – (
Changes in Insurance C
Equipment Effected by
Assessed Value $6,000 $4,500
Tax Rate 0.005 0.005
Assessed Value of Equi
x Tax Rate 0.0
Cost of Breakage $
Per Cent Saved or Lost $
Cost of Increase (+) or D
of Product Due to Hand
Cost of Accidents $ Per Cent Saved or Lost $
Cost of Increase (+) or D
to Workmen Due to Ha
Value of Investment Gained or Lost $
Interest, Depreciation, Insurance, Tax Rate $
Depreciation, Interest, Insura
Cost of Taking Inventory $
Per Cent Saved Taking Inventory $
Increased (+) or Decrease
Increased (+) or Decreased
Inventory $
Amount of Floor Space
Unit Value of Floor Space
Yearly Value of Floor Spa
Gained (–) or Lost (–) for
Number of Machine Hours Saved or Lost
Value per Machine Hour $
Building Maintenance $
and Building Changes $
Repairs to Floors, Installation of Sa
Devices, Changing Wall and Door O
Strenghtening Superstructures, e

HANDLING CHECK CHART
s Governing Final Selection of Equipment

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July, 1935

Required 2 3
40¢ 40¢
12¢

Total Hourly Labor Cost $1.04 $1.56
÷
Amount of Material Handled per Hour: 30 tons 30

per of Cycles (two trucks)
nt of Material 1 ton

→ Unit Labor Cost $0.035 per ton
$0.052 " "

Power Cost per Hour $0.10 $0.05
÷
Amount of Material Handled per Hour 30 tons 30

→ Unit Power Cost $0.003 per ton
$0.0015 " "

Annual Cost of Repairs and Maintenance $300 $100
+
Cost of Lost Production During Breakdown $300 $300
÷
Total Material Handled per Year 48,000 tons

→ Unit Repair and Maintenance Cost $0.013 per ton
$0.009 " "

→ Total Unit Operating Cost
$0.051 per ton
$0.0625 " "

nent $8,000 $4,500 + Cost of Changes
all $0 $1,500 Salvage Value $500 $500
ful Life 5 5 Years (corrected for
scence and possibility of change)

→ Depreciation $1,500
$1,100

8,000 $6,000 + Value of Production Lost
lation $0 x Interest Rate 5% 5%

→ Interest on Investment
$400 $300

8,000 $6,000 x Insurance Rate 1.5%
sed) or – (if reduced)
nsurance Costs on Buildings and
ffected by the Installation

→ Insurance $120 $90

lue of Equipment $6,000 $4,500
Rate 0.005

→ Taxes $30 $22.50

ase (+) or Decrease (–) in Breakage
ue to Handling System $_____

ase (+) or Decrease (–) in Accidents
Due to Handling System $_____

erest, Insurance and Taxes on Inventory $____

or Decreased (–) by Handling System Plus
Decreased (–) Cost of Taking
---

of Floor Space
Lost (–) for Productive Operations $_____

_____ Idle Machines $_____

ation of Safety
and Door Openings,
ructures, etc. $___

Building Maintenance Changes $___

→ Indirect Charges $___

Total Yearly Fixed Charges $2,050 $1,512.50
÷ Total Yearly Amount of Material Handled 48,000
= Total Unit Fixed Charges
$0.043 $0.0315

→ Total Unit Materials Handling Cost: $0.94 per ton
$0.94 " "

INVENTORY CONTROL

AUTHOR

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Associate Editor

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CHAPTER ONE

Need to Overhaul Current Practice

THERE are several reasons why inventory control receives less attention than formerly. The primary purpose of a stock is to provide a cushion against irregularities of supply and demand, and as we have learned to control production more accurately, the size of stocks has declined and storerooms have been turned to other uses. For several years a declining market has emphasized the drive for lower inventories. Finally, many of the discretions that the purchasing agent and storekeeper used to exercise, in such matters as specifications for kind and quantity of materials, have been transferred to other departments such as engineering or production.

For these and similar reasons there have been fewer new and radical developments in this field than in some others. Nevertheless, some of the knottiest unsettled problems in manufacturing are found here. The valuation of an inventory is one of the more difficult problems of internal accounting, and the determination of the economic lot size is still guessed at by the majority of storekeepers, although it is not uncommon to find a third or more of the total company capital tied up in inventory.

There's Profit in Control

There are indications that the immediate trend will be to reverse some of these influences and to emphasize the importance of storekeeping and materials control as a factor in profits. Prices have moved upward for the past several months, indicating the likelihood of more forward buying. Companies in a number of important lines have been accumulating stocks as an insurance against possible shortages resulting from labor troubles. Many companies have so scaled down productive capacity that even a small increase in demand finds them unprepared; others are enjoying really substantial increases in sales.

In consequence, we begin to hear again of factories whose capacities are booked for weeks or even months ahead. Stocks must be increased in response.

All of these factors indicate the advisability, in tuning up production to meet tomorrow's need, of overhauling inventory control practice as we know it today.

In this control, there are a num-

ber of major functions. Procuring and carrying materials is a speculative activity, both from the standpoint of price and from that of an advantageous market for the products purchased. Purchasing and inventory control are thus intimately linked with some of the most important financial, marketing, and production problems of the business.

In the second place, the carrying of an inventory involves definite costs, and presents a problem of the control of these costs for lower overall results.

Third, there is the problem of valuing the inventory to aid the accountant in correctly ascertaining the profits and financial position of the business.

Fourth, necessary to an adequate control of these factors is the keeping of dependable records at all times of the materials on hand.

Finally, there are all the numerous problems involved in caring for and conserving materials physically, protecting them from loss, theft, or damage, making them easily and quickly accessible when and where needed, all with the minimum of labor and effort. Each of these problems, in turn, implies various problems of securing an effective organization, both of men and of equipment, to get the desired results.

CHAPTER TWO

Speculative Elements

ONE of the more common of the hidden costs of manufacturing is the writing off of obsolete inventory, or the closing out at a loss of style goods for which the market has proved disappointing. In part, the prevention of such losses is the function of the sales department, by correctly estimating the tendencies of the market. The beginnings of inventory control, however, lie in these estimates.

How Markets Develop

The problem of estimating demand varies greatly between industries. In the manufacture of many lines, obsolescence due to improvement of processes and new inventions is the principal factor likely to cause rapid changes, although even such industries as the making of machinery are indirectly affected by changes in style, taste, and need in the consumer lines to whose production they ultimately contribute. The increasing use of automatic heating plants in the home has, for example, enlarged the markets for a variety of paints and interior finishes, wallboard, porch and rustic furniture, games, inexpensive decorations, furniture, and equipment suitable for renovating the basement.

Similarly, the emphasis on the comparison of heating costs has encouraged the use of insulating compositions both in building new homes and in treating existing structures. At least two electrical manufacturers are featuring exhaust fans for the quick cooling of attics and upper stories. A whole new family of new or increased wants is thus developing out of one basic improvement. Many other cases could be followed through in the same way.

While the prediction of the market for individual items still contains many speculative elements, considerable progress has been made in estimating demands. The demand for a new product tends to follow the typical growth curve, increasing at first slowly, then more rapidly—then, as a point of saturation is approached, more slowly again.

How Styles Spread

The growth of demand may also be compared to a series of waves, propagated from point to point. Movies, illustrated magazines, the increase of travel and organized national advertising and marketing, have combined to spread new styles very rapidly over the whole country, once they are introduced. But in each locality there are those who are quick to adopt the new style because of ample means, social position, or suggestibility, and those who wait until everyone else has made the change.

The Way of Fashion

In consequence, there is a more or less definite order of development of a new fashion. First sales are usually at higher prices, in the smaller and more exclusive stores. The broader volume will continue to develop over a period ranging from several months to several years, presently to give way to something else in fashion merchandise, or to establish itself until displaced by another basic improvement or change in conditions or habits.

If a manufacturer follows the sales of a new item carefully for the first few weeks or months, particularly in a few of the stores looked to by the public as leaders from the standpoint of exclusiveness and novelty, he can closely predict the total demand for the article.

Forecasting price changes is probably more speculative in most cases than that of general style trends. The broad movement of prices upward or downward may continue in one general direction for a decade or more, but individual commodity prices are affected by eddies of shortage or over-production, either of the article itself or of its component materials, which require the closest attention on the part of the purchaser. In contrast to the often highly speculative buying policies of the past, the apparent present tendency on the part of manufacturers has been to avoid heavy forward buying and to concentrate on manufacturing rather than speculating.

Emphasis on standard costs has brought the question of price levels of materials even more into the foreground in recent years and made the estimating of price trends important to the comptroller as well as to the purchasing agent. Standard costs also permit measurement of the effectiveness of the purchasing department. In many lines, published market and price data permit the average price of a commodity over any period to be computed and compared with the price actually paid during the same period.

CHAPTER THREE

Economic Lot Sizes

ALTHOUGH the estimation of sales requirements is not normally a primary responsibility of the material procurement department, a knowledge of the factors that influence the growth and later decline of sales will make a more intelligent control of inventories possible and will be of particular value in knowing how to deal with slow-moving and obsolescent stocks.

Usual mechanisms for the control of stocks are very closely related to and a part of the plans of production control, already described in this Plant Operation Library.[1] The tendency is toward a control of manufacturing, as of stores also, on a definite quota or budget basis. For example, in style lines there is an active pre-season campaign to show the goods and to secure advance orders for them.

Such exhibitions as the furniture shows, radio shows, automobile shows, toy fairs, style shows and outdoor sports displays provide an opportunity to test the popularity of new lines and the trends likely to affect old established ones.

Budgeted Production

Information brought in from these sources is combined with a careful canvass of dealers by the company's salesmen, which often extends to the estimating of probable sales in every basic pattern or style. On the basis of this information, together with data supplied by the general administrative and statistical departments as to probable buying power, quotas are set for every pattern manufactured, specifying the total estimated demand. Releases against these quotas are made cautiously at the beginning of the season—one company releases only 40 per cent of the quota initially—and then more fully as the season advances and buying tendencies manifest themselves.

In all style industries, embracing most of the important consumer lines outside of foodstuffs, it is of primary importance to end the season with the storeroom shelves clean. The whole problem is that of estimating the demand closely and meeting it exactly; manufacturing methods must accommodate themselves as best they may.

Manufacturers of novelties therefore sacrifice the economies of large runs in order to be able to fill orders quickly, and to make up stock only at the times and in the amounts demanded by the market. Manufacturers of more staple items such as cars, furniture, and radios are able to schedule in larger quantities, but are equally careful to guard against the accumulation of excess stock, except in staple parts and raw stock that can be used next season.

Where style influences are incidental or absent and there is considerable variety of product, the economies of quantity manufacture or purchase usually indicate the stock-limit plan of control. Orders either for purchase or manufacture are originated by the stock-record clerk when the balance of any item reaches the minimum, and the amount he orders is regulated by the maximum.

Orders for items not regularly stocked, and in some cases certain other orders, may be placed directly with the purchasing agent by the production order department, only a memorandum copy being sent the stock-record clerk. But in theory, under this system of control, and in practice to a very large extent, the storekeeper is the factory's only customer.

Under this system, the setting of stock limits becomes an important job. It is frequently handled by the superintendent, who goes over all the stock records at the beginning and end of every active season, or at intervals of 6 months or less, revising the limits upward or downward as may be indicated. Where the production department is coordinate with rather than subordinate to the

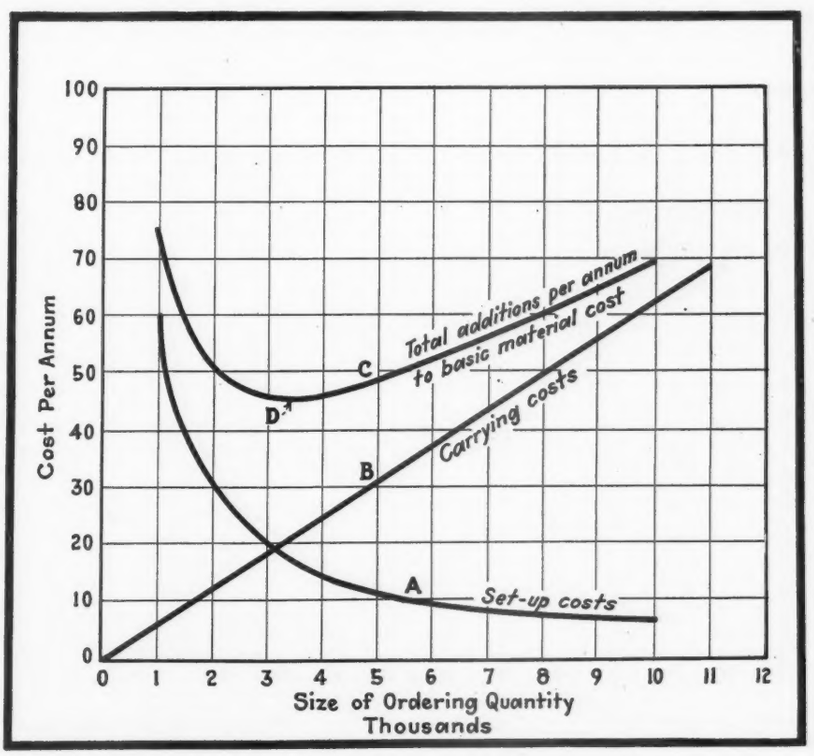

Figure 1. Sum of set-up and carrying costs equals total unit cost for any lot size. This addition is performed graphically in *C*. Point *D* indicates the economical quantity in which to order the item

[1] "Production Control," H. P. Dutton, p. S45, *Factory Management and Maintenance*, June, 1935.

superintendent, as it is in many larger organizations, it usually handles the setting of stock limits.

The theory underlying the setting of stock limits has been understood for many years, but the job is still done by guesswork in many plants, which shy at the simple mathematics involved. As with the Gilbreth system of motion analysis, factory executives took one look, found the formulas too much for them, and dismissed it all as "impractical."

Only recently has the writer found an example of the routine application of the stock-limit formula, using a slide rule to speed up and simplify the arithmetic. An example given in Figure 3 shows the extent of the annual difference in cost, 4 per cent, between a correctly set maximum and the very reasonable guess of approximately semi-annual orders.

Worth Saving

On a stock worth $100,000, a 4 per cent saving would pay for $4,000 worth of clerical labor, and with virtually no initial investment.

If stocks are relatively small, computation of limits may not pay, although even here sample computations should be made for a sufficient range of cases to develop a correct judgment as to similar cases.

Where a company's investment in stock runs into large amounts of money, however, the slight expense involved in setting correct limits will be paid for many times over.

The factors determining the *minimum* limit are three: What is the average rate of use of the article? How long, after placing the order, before it will be delivered? If no allowance had to be made for irregularities in demand or supply, the "minimum," or ordering point, would simply be the product secured by multiplying these two quantities. Because it is not safe to count on such uniformity, a small reserve will be added to the ordering quantity.

"Minimum," although a commonly used term, is misleading. Use of the stock goes right on after the minimum limit has been reached. The "minimum" is simply a flag to indicate the point at which the new order is to be placed. If 1,000 units were used a week, and it took two weeks to put a new order through, an order placed when the stock on hand fell to 2,000 would arrive just as the last material in stock was being issued. This would be the ideal condition. Reserve against irregularities is normally dead stock, and should be kept as low as adequate service to customers and avoidance of interruptions and extra costs of rush shipments will permit.

Setting a "maximum" is governed by a different set of considerations. Either in manufacturing or buying for replenishment there are two opposing sets of cost factors to be considered. Every time an order is put through, a variety of clerical and factory costs are incurred. Orders must be written, issued, followed up; time cards and inspections will be required; the machine must be set up and cleaned up.

Trend of Set-Up Costs

Costs of this nature, when expressed as costs per unit, decrease as size of order increases, at first rapidly, then more and more slowly until the decrease is negligible.

The trend of these costs (indicated by curve *A* in Figure 1) is most clearly evident in orders the company makes up itself. They must be included in some approximate way, however, in the costs of purchased materials. The vendor who bids on the company's requirements, the railroad company that transports them, must recoup themselves for a like series of set-up costs. Estimates, quantity discounts, and carload rates will reflect the same trend.

On the other hand, the larger the

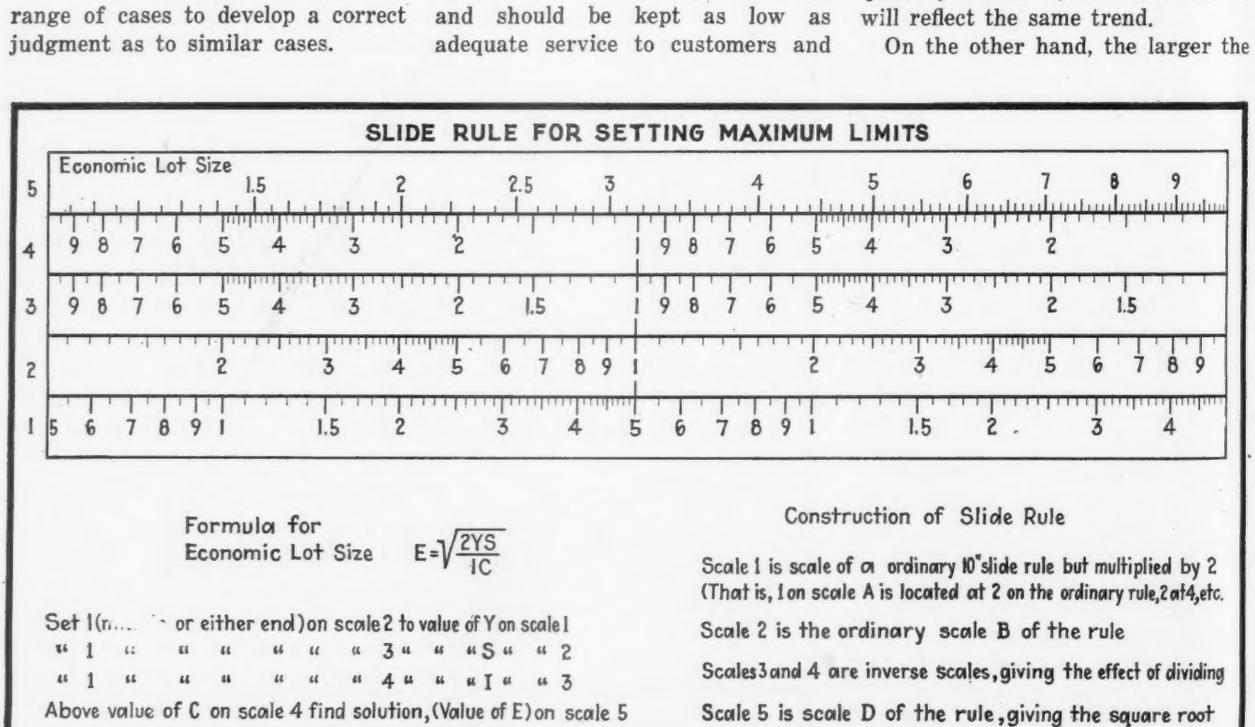
SLIDE RULE FOR SETTING MAXIMUM LIMITS
Economic Lot Size
Formula for Economic Lot Size $E=\sqrt{\frac{2YS}{IC}}$
Set 1 (r... or either end) on scale 2 to value of Y on scale 1
" 1 " " " " " " 3 " " "S " " 2
" 1 " " " " " " 4 " " "I " " 3
Above value of C on scale 4 find solution, (Value of E) on scale 5
Construction of Slide Rule
Scale 1 is scale of an ordinary 10" slide rule but multiplied by 2 (That is, 1 on scale A is located at 2 on the ordinary rule, 2 at 4, etc.
Scale 2 is the ordinary scale B of the rule
Scales 3 and 4 are inverse scales, giving the effect of dividing
Scale 5 is scale D of the rule, giving the square root

Figure 2. Special slide rule designed to speed up the process of solving the formula for economic lot size

quantity made up at one time, the larger will be the average inventory. Consider a product used at the rate of 1,000 units a week and assume that four weeks' supply is ordered at one time. Assuming a uniform rate of use for simplicity, and no reserve included in the minimum, the stock will fluctuate from 4,000 down to zero and will average 2,000. Increase the ordering quantity to eight weeks' supply; quantity used per year will remain the same, but the average inventory now varies between 8,000 and zero, is double what it was before.

To justify a larger stock, the investment should yield at least as large a return as could be earned on the same money put to other uses, or say the going rate of interest. Also, the larger the inventory, the longer the material is in stock and the greater the risk of deterioration and loss of value due to style changes or other obsolescence factors.

The Larger the Lot—

Handling and providing storage space for the larger inventory will also increase costs. In short, assuming a constant rate of consumption in all cases, the larger the lot the larger will be these carrying costs. Per unit, they will increase in proportion to the increase in lot size. This relationship is likely in practice to take on increase by irregular steps rather than a straight line (such as *B* in Figure 1).

Under many conditions, for example, small increases in lot size will involve no increase at all in storage costs until the capacity of the present storeroom is reached. Then there will be a sudden large jump.

The sum of the set-up costs and the carrying charges will give the total unit costs for any lot size. This addition is performed graphically in curve *C* in Figure 1. There will be in general a point *D* at which the total cost is least, and which is the most economical quantity to order.

No account has been taken in this solution of the possibility of price fluctuations. If prices are trending upward at an estimated rate per month, the advantage of buying immediately rather than at a later time may be expressed as a decrease in the carrying charge, or if the trend is downward, as an increase.

Quite evidently there will in many cases be large uncertainties and rough approximations in determining the elements in this cost comparison. It may be asked whether any better results will be secured than by a good frank guess. The question answers itself. Separate estimates are by their nature more accurate than are composite guesses.

These relationships may be expressed in several ways. The separate costs may be computed and tabulated for a series of different and progressive lot sizes, and the lowest points selected. Or graphs like Figure 1 may be made.

A quicker and more practical solution is by formula. It is possible by calculus to solve the cost equation for curve *C* and to find the lowest

COMPUTATION OF LIMITS BY FORMULA

Item: Coil Spring

Unit Cost (C): $0.035

Set-up Costs (S):	Machine set-up, ½ hour @ 1.00 for labor and burden	0.50
	Clerical and general charges per order	0.65
	Total set-up cost per order per annum	1.15
Carrying Costs (I):	Interest	6%
	Depreciation	20
	Storage, miscellaneous	4
	Total carrying cost per annum	30%

Average Consumption (Y) 1,000 per week. Time required to fill orders, 1 week. Reserve supply, 1,000

Minimum or ordering point:	Reserve supply	1,000
	Use per week (1,000) x 1 week	1,000
	Ordering point or minimum	2,000

Quantity to order or maximum:

$$E = \sqrt{\frac{2YS}{IC}} = \sqrt{\frac{2 \times 52{,}000 \times 1.15}{0.30 \times 0.035}} = 3{,}374 \text{ or say } 3{,}500$$

COMPUTATION OF LIMITS BY TRIAL AND ERROR

Maximum	Average inventory (max./2 + reserve)	Average investment (0.035 each)	Carrying charge per annum	Number of orders placed per annum	Total set-up costs per annum	Total extra cost per annum	Basic material cost per annum ($18.20) plus additional costs	Percentage increase over cost in lots of 3,400
1,000	1,500	52.50	15.75	52	59.80	75.55	1,895.55	1.6
2,000	2,000	70.00	21.00	26	29.90	50.90	1,870.90	0.3
3,000	2,500	87.50	26.25	17.33	19.93	46.18	1,866.18	0
3,300	2,650	92.75	27.83	15.76	18.12	45.95	1,865.95	0
3,400	2,700	94.50	28.35	15.29	17.29	45.94	1,865.94	0
3,500	2,750	96.25	28.88	14.86	17.08	45.96	1,865.96	0
4,000	3,000	105.00	31.50	13	14.95	46.45	1,866.45	0
5,000	3,500	122.50	36.75	10.4	11.96	48.71	1,868.71	0.2
6,000	4,000	140.00	42.00	8.67	9.97	51.97	1,871.97	0.3
7,000	4,500	157.50	47.25	7.43	8.54	55.79	1,875.79	0.5
8,000	5,000	175.00	52.50	6.5	7.47	59.97	1,879.97	0.9
9,000	5,500	192.50	57.75	5.77	6.64	64.39	1,884.39	1.0
10,000	6,000	210.00	63.00	5.2	5.98	68.98	1,888.98	1.2
20,000	11,000	385.00	115.50	2.6	2.99	118.49	1,938.49	3.9
52,000	27,000	985.00	295.50	1	1.15	296.65	2,116.65	13.5

Figure 3. Comparison of the results obtained in computing economic lot size (a) by formula, (b) by trial and error

point at which the slope of the curve is zero. It is not necessary to understand the derivation in order to use the formula. This derivation, which is available in a number of standard texts, will not be repeated here.[1] A comparison of results, using the formula and by tabulation, is given in Figure 3 and shows how the formula is worked out. A few similar comparative solutions in given cases are helpful in grasping the principle.

The formula is as follows:

Economic lot size =

$$\sqrt{\frac{2 \times (\text{Quantity used per year}) \times (\text{Set-up cost})}{(\text{Per cent of carrying charges}) \times (\text{Cost per piece})}}$$

$$\text{or } E = \sqrt{\frac{2YS}{IC}}$$

Solution Is Simple

In this formula Y represents the number or quantity of the part used per year. S, the set-up cost, includes machine set-up costs and all other elements that are the same for any size of order. Machine set-up allowances should be available in the records of the rate-setting department. Standard figures applicable to broad classes of orders may be developed for the clerical and other elements—other than machine set-up—in this factor.

Factor I includes interest, depreciation and obsolescence, taxes, insurance, rental, and handling charges, and all other costs tending to increase proportionally with increases in inventory.

C is the cost of the material per unit. If the set-up cost is included, as it should be in theory, this cost will vary with quantity. Practically, except for very small lots, a sufficiently accurate solution may be made by taking this cost as a fixed figure for each article, the sum of labor, material, and burden as given by the cost records.

This formula may be solved very simply, once the values are known for its elements, with an ordinary slide rule, or a special rule (see Figure 2).

A modification of stock-limit control often used is the statement of the limits in terms of number of weeks' use instead of as quantities. The limit would be found in this case by solving as before for the correct quantity and translating this into terms of time. While the solution would be theoretically correct only for one rate of use, in certain cases it has the practical advantage of automatic adjustment to variations of demand.

The entire structure of stock limits should be reviewed systematically at regular intervals. To assist in judging probable consumption of the article for the next period, a summary should be available of the amounts of the article used, by six-month or annual periods. Some types of stock records yield this record as part of their normal use; where they do not, the stock clerks can total the consumption in advance of the periodic review.

In making the revision, the general trend of demands for the article, or for the products with which it is associated in assembly or sale, will be considered. It is here that a knowledge of the demand pattern for style and other types of goods is helpful in making a correct estimate. In some lines that are seasonal but only incidentally affected by style factors, the stock limits are revised at the opening of the busy season in early spring, and set back to lower levels at the close of the season—each time, of course, taking into account changes in demand affecting individual items.

Checking "Poor Movers"

Periodic revision may also be made the occasion for a review and disposal of obsolete or obsolescent items. On each of these items, the stock clerk may make out a report showing the number of transactions in the past year or the number of years since the last transaction, the quantity and value of the stock on hand, its location in stores, the assembly on which the item is used and the names of other uses to which it could be put, and such other information as may be obtainable as to the markets and probable price for the material as junk.

On the basis of these data, the superintendent, or preferably a committee including the chief engineer or his representative, a representative from the sales department, the purchasing agent, and the superintendent or factory or production manager, will decide on the disposition of the item.

Incidentally, it is important to provide a routine by which the stores department may be notified at the earliest possible moment of impending changes in pattern. Change orders should clear through the stock records as a matter of routine. But even before this—indeed, the moment a change is first suggested—either the storekeeper, superintendent, or production superintendent, or whoever is responsible for ordering, should be notified that a change is in prospect and warned to go easy on re-orders until he has checked the developments of the experimental item.

Adjustment to Change

This difficulty is taken care of automatically under the quota plan of production and inventory control, where orders are issued only against specific sold business or estimated sales, and where any change in estimates or orders is immediately taken up by adjustment of outstanding production orders.

Both the ordering point and the quantity to order can be controlled without perpetual inventory records. The minimum or ordering point is sometimes indicated by tying the minimum stock into a bag or by otherwise physically separating it. When the stock man draws the item down to the point where none is left except that thus set aside, he reorders. The amount of the reorder may be indicated by attaching a tag to the bag, which carries the name and pattern number of the item, and the reorder quantity.

The advantages of setting correct stock limits is relatively as great in the small business as the large one. There may not always be an equal case for stock records in the smaller business, where stocks are simple, few and constantly under the manager's eye, and where adequate control may be had without records.

[1] See "Economic Lot Sizes," F. E. Raymond, *Factory and Industrial Management*, July to December, 1930.

CHAPTER FOUR

Perpetual Inventory Records

IN STRAIGHT-LINE manufacturing, perpetual inventory records may sometimes be modified, omitted, or restricted to certain items. In this type of production control the material moves in a thin, rapid stream through the various processes. At each process or major process group, a small bank of material is usually allowed to build up before the stream of parts reaches the next operation as a cushion against temporary interruptions or irregularities.

Once built up, this bank remains approximately constant. At the conclusion of the run, the bank is turned back into the production stream and thus all of it must appear in the final accounting for deliveries. In this case, the accounting records will usually be limited to records of the raw materials on order and on hand, of the deliveries against these materials to production, and of the deliveries of finished product by production.

Records That Are Needed

A form suitable for this condition was shown in Figure 1 of the previously mentioned section on *Production Control* in the June issue. Stock records, however, become a necessity in the larger business.

For businesses using the stock-limit plan of production control, the type of record shown in Figure 4 is usually employed.

One form of this record, as illustrated in this figure, restricts the entries to physical transactions.

Another form, shown in Figure 5, also provides columns for the apportionment of stock against customers' orders for future delivery, with a corresponding balance of stock unapportioned and available.

Apportionment of stock required for filling customers' orders is useful in case these orders are likely to be large in proportion to the average stock carried. Where orders come in irregularly, and frequently for comparatively large amounts of stock, if one relied solely on the balance on hand to know when to re-order, it would be possible to get badly behind, not having a record of the large amount of customers' orders accumulating for delivery in the near future. By deducting such orders from the balance on hand in order to indicate the balance available for new orders, and by re-ordering when the available balance reaches the minimum stock limit, this danger is eliminated.

Not Much Trouble

The extra work of recording or "apportioning" the customers' orders is not great. The largest amount of time in making an entry in the books is probably spent in locating the item and getting out the book or card, in reading the requisition, order, delivery slip, or other item being entered, and in replacing the book or card. Writing or making the entry does not take long.

The keeping of an apportionment record necessitates a complete clerical operation for each customer's order, and a partial operation involving only a slight addition to total time, when the order is filled. This extra work will usually be omitted when the average stock is large relatively to the average order.

In Figure 5 a perpetual balance is carried both of material on hand and available for customers' orders. When an order is placed for stock, it is carried also to the "available" balance. Normally, it will be received before the minimum, on hand at the time of ordering, is exhausted. On receipt of the material, the entry in the "ordered" column is cancelled or deducted, and the amount is carried to the "received" and "balance on hand" columns. On receipt of a customer's order for future delivery, the item is posted to the "apportioned" and deducted from the "available" columns.

When the customer's order is filled, the "apportioned" item is canceled and a deduction is made from the "issued" and "balance on hand" columns. A check is obtained on the accuracy of the clerical work by the fact that the sum of the balances in the first two columns, "ordered" and "on hand," will always equal the sum of the balances in the last two.

Easier to Add

Another method of carrying balances is simply to carry cumulative totals of the stock ordered, received, and delivered. This method would be particularly applicable to a system of quota stock control. The balances on order or on hand may be found at any time by deducting the "received" balance from the "ordered," or the "balance delivered" from that "received." It is claimed in favor of this method that, because it is easier to add than to subtract, fewer clerical errors will be made and less time taken.

Perpetual inventory records may

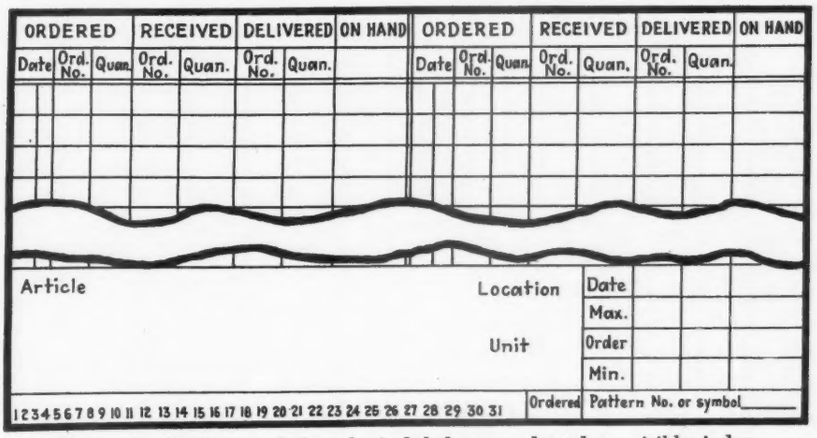

Figure 4. Stock record for physical balances, adapted to visible index. Flags attached to lower edge indicate follow-up dates

BALANCE OF STORES SHEET

NAME OF ITEM *Coil spring*
SPECIFICATIONS *15*

Quantity used in period ending: Date | Quantity | Date | Quantity
Date | Minimum | Quant. to order | Symbol *CS-15* | Location | Unit

ORDERED			RECEIVED			ISSUED			BALANCE ON HAND		APPLIED ON ORDERS			AVAILABLE		REMARKS
Date 1935	Quantity	Purch. or stock order No.	Date	Quantity	Price	Date 1935	Quantity	on order No.	Date 1935	Quantity	Date 1935	Quantity	Order No.	Date 1935	Quantity	
8-5	3,500	S1124	8-12	3,508	0.035	9/1	150	C4885	8-12	3508				8-5	3500	S-11,2
8-16	3,500	S2011							9-1	3358	8-10	150	✓ C4815	8-10	3350	C4885
														8-16	2358	over delivery
											8-16	2000	C5016	8-16	1350	C5016
																2011

Figure 5. This type of stores record shows material on hand and what portion of it has been "earmarked" for customers' orders

be handled physically in several ways. A loose-leaf book serves well. Card indexes are also widely used, the cards being kept in filing tubs where the number is large. Visible indexes of the "shingle" type are convenient, especially when the cards are referred to often. The name and pattern number of the item are typed on the bottom margin of the card, and metal flags may be used to indicate the exhaustion of stocks and to make it easy for the superintendent to locate stocks that may supply work for temporarily idle departments.

Forms to Fit the Need

The use of book inventories implies that a written record shall be made of every stock transaction. Typical requisitions for materials and credits for returned goods are shown in Figure 6. Where tabulating machines are used, forms will be adapted to standard columns.

Forms must of course be adapted to a wide variety of situations. Requisitions for parts for assembly are often in the form of standard lists in which, aside from the order number, only the quantities need be filled out, in multiples of the ordered quantity. In other cases, a copy of the production order, prepared by hektographing, fanfold typewriting, or other means, will serve as the requisition.

A special case is met where work on an order is spread over several days or weeks and materials must be drawn out in small lots at frequent intervals. In such cases, for materials in frequent use, it may be possible, as Farwell suggests, to use a requisition bearing on its face a series of digits, fives, tens, or other convenient units in which the material is likely to be wanted, and which can be punched out with a conductor's punch as the material is used against the requisition.

With small items the clerical cost of making out and handling the requisition may frequently exceed the value of the item drawn. Where there is only an occasional case of this sort, it is better to let the requisitions go through rather than complicate the general clerical procedure.

Where the small items predominate, as in filling numerous small orders from stock, it may be better practice to do away with detailed requisitions. One company meets this situation by keeping stock records only of case lots and bulk issues. A separate section of the stockroom is set aside for order picking, and in this section are stored small quantities of the items commonly called for. These small stocks are controlled by physical minimums (parts tied up in bags or separated at the bottom of the pile by cardboard dividers), and tags at each bin indicate the number to be re-ordered.

No Record Kept

Order pickers draw from these shelves without record. When stock is replenished from the main storeroom, a requisition and record are used in the regular way. About 10 per cent of the total inventory is normally on the order-picking shelves. This stock is inventoried periodically, and the balances are checked against the aggregate issues from the main storeroom and aggregate shipments on customers' orders.

In many factories operating on a quota plan of production control, it is possible to issue parts and materials in specified daily quantities without requisition, the stock records being posted from the production orders. Requisitions are used only for occasional and irregular orders.

MATERIAL AND SUPPLIES RETURNED TO STOCK — Lot No. | Stores register No.

TO STOCK CLERK AT _____ DATE _____ 19__
RETURNED FROM _____

Order and item No.	Quantity	MATERIAL

MATERIAL DELIVERY SLIP — Lot No. | Stores register No.

TO STOCK CLERK AT _____ DATE _____ 19__
REQUIRED AT _____ DELIVER TO _____

Order and item No.	Quantity	MATERIAL	Car No.

Car No.	ORDERED BY	RECEIVED		QUANTITY	UNIT	PRICE	PER	AMOUNT
.....	.....	.....	Date					
Carrier	Foreman or clerk	Foreman						

Figure 6. Typical requisition and credit slip for goods returned to stock

CHAPTER FIVE

Taking Physical Inventory

WERE EVERY transaction correctly made, there would be no occasion for taking a physical count; the book inventory would suffice. It is not safe, however, to assume such a degree of accuracy. The records must be verified to prevent possible cumulative errors and discrepancies. Where no record is made of detailed transactions, the taking of an inventory is a necessary step in ascertaining the profit for a period.

The difficulties of getting an accurate count with a temporary crew and with material constantly entering and leaving the storeroom and the plant are considerable. In the past it was customary to shut down the plant in order to get a reliable inventory. Occasionally this is still done. While it may be practical to inventory during an off period when the factory would be idle in any case, it is no longer considered necessary to interrupt production when good stock records are kept.

Bin Tags Help

No mention has so far been made of bin tags. A bin tag, such as that shown in Figure 7 is in reality a simplified perpetual inventory record kept adjacent to the material. The stock man, as he receives or withdraws material, enters the item in the "in" or "out" column and carries down the balance on hand.

An advantage of the bin tag is that at any time the accuracy of the stock man's work may be verified. Also, when the stock is reduced to zero or a small quantity, it is a simple matter to count what is in the bin, record it on the tag as an "inventory," carry the balance on hand forward onto a new tag, and return the old tag to the stockroom for comparison with the book records.

If these are found in agreement, the fact is noted by marking "INV" with the date, after the checked balance on hand. All columns should then be ruled off so that entries subsequent to the count may be clearly distinguished. Slight discrepancies, which might arise from inaccuracies of counting scales, or from similar causes, will ordinarily be overlooked and the balance simply corrected. Larger differences should be traced back and the responsibility for making the error fixed.

A Systematic Count

This plan will provide a fairly frequent check on the active items. Since we cannot rely on covering all items in this manner, many companies follow the plan of having one or two men systematically count every item in stock once or twice a year, or in some cases, where a high degree of dependability in records has been attained, once in two years. Frequently the bins will be selected at random each morning from those not yet inventoried, so that the stock men will not know when their divisions are going to be checked.

In spite of the convenience of bin tags in taking the inventory, a question is sometimes raised as to their advisability. Against their use it is urged that they must be kept up by stock men who usually have no experience in clerical work, and in consequence the records are apt to become inaccurate. Keeping them up also increases the clerical work, both for the stock men and for the stock record clerks.

Favoring the use of bin tags is the check they give, to the stock man as well as to the chief storekeeper, on the correspondence of the records and the stock. Much stockroom work is intermittent, so that the use of tags seldom results in any increase of force or serious burden on stock men.

Of course it is hopeless to expect records or stocks to be kept in good shape where several or many people have access to the various sections of the storeroom. A first principle of storeroom management is that responsibility for the condition of each section of stock should rest definitely on one man; no one but this man or other men working under his supervision should have access to the section. Where this rule is in effect, the simple entries required by the bin tag present little difficulty and they make it easy for a supervisor or the stock man himself to check the condition of his section by spot counts. The stock man will tend to develop a better grasp of his work.

Bin tags are in general more suitable to industries that carry a wide variety of parts, particularly where the parts are used year in and year out, than to businesses run on the quota plan, or to seasonal and style businesses where lots of stock are run through and cleaned up except for possible odds and ends. In the industries to which bin tags are adapted, it might be possible to do without them if the crew is trained to accuracy in handling stock, but the man who can keep his stocks in shape without the bin tags is likely to do a better job with them, and without much extra work.

Bin tags greatly facilitate the taking of periodical, over-all inventories. Tags may be used temporarily for this purpose even when not regularly employed.

In taking inventory with the aid of bin tags, the balance on hand will be picked up and verified by count if the tag is in regular use. If it is not, a count will be made and entered on a tag attached to bin or material.

This work of counting and recording can, if necessary, be spread over a period of a week or two. Receipts and withdrawals subsequent to the making of the count are entered in the usual way in the "in," "out," and "balance" columns.

Day of Reckoning

On the day of the official inventory, crews of two men go rapidly and systematically through assigned sections of the storeroom. One man has a supply of inventory tags, such as illustrated in Figure 8, filled out from the stock records with the name, part number, and location in stores of every item in the assigned section for which there is a stock record. These cards are numbered serially and must all be accounted for. The two men take each bin as they come to it, and while one finds the proper tag, the other removes

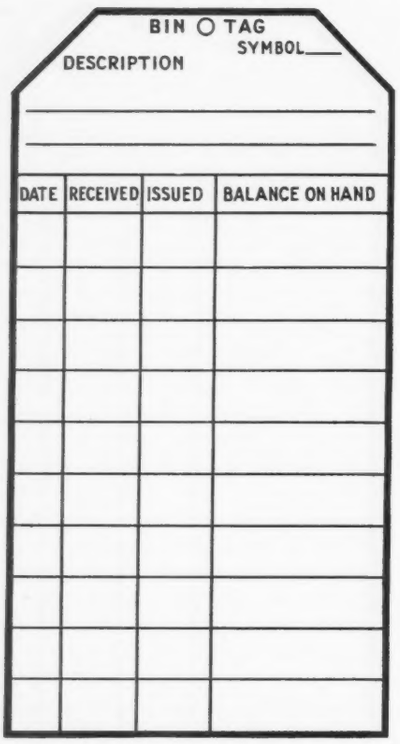

Figure 7. Perpetual inventory records kept adjacent to the materials entail a little clerical work by stock men, are usually worth it

the bin tag from its metal pocket on the bin.

Pattern number and description are checked to make sure that they correspond and all entries on the bin tag, subsequent to and including the inventory count, are transferred to the record half of the inventory tag. The other half of this tag is now torn off and placed with the bin tag in the metal pocket, where it is left until the inventory has been completed, verified, and approved, serving to indicate which items have been counted and to make it possible to check any errors.

Perhaps some materials will be found for which there is no office record. If so, a tag will be filled out for each, description and pattern number being taken from the bin tag if one exists. For other items for which cards are supplied, no stock may be found; the fact is indicated.

As each crew completes its batch of cards, it turns them in, and they are checked by serial number for missing cards, which must be located before the crew is excused. They are next sorted by pattern number and cleared through the stock records, also a job that may safely be spread over a week or so, since the cards contain a chronological record of all transactions subsequent to the count and up to the short, complete cut-off of the half day during which the cards are "pulled."

Official Inventory

The stock record clerk will reconcile the transactions on the inventory tag with the entries on his own books, and can thus trace any that may not have cleared through either record. While reconciling the balance he will investigate any serious discrepancies, will adjust his books, call for a recount if necessary, or take such other steps as may be needed to assure accuracy. The verified tags will then be priced and turned over to the accounting department, where they will be extended, classified, and totaled to give the official inventory.

In a storeroom where the records are in good shape and the clerks and stock men well trained and disciplined, it should be possible, without interrupting production, to obtain an agreement between book inventory and physical count with less than one-tenth of one per cent of variation.

The spreading of the count, made possible by carrying current transactions forward to the bin tags, makes it possible, if the inventory does not come at a rush period, to do practically all the work with the regular storeroom crew, the only precaution being to assign crews to sections other than those in which they regularly work. The work can easily be inspected by spot counts here and there after the crew has made its count and entered it on the tag. It is a great advantage to have the work done by trained men, thereby avoiding both the need of training crews and the confusion likely to result when temporary crews must handle and replace all the stock.

Where bin tags are not used, the general procedure for taking a periodic inventory will be much the same except that it will usually be necessary to shut down for the period

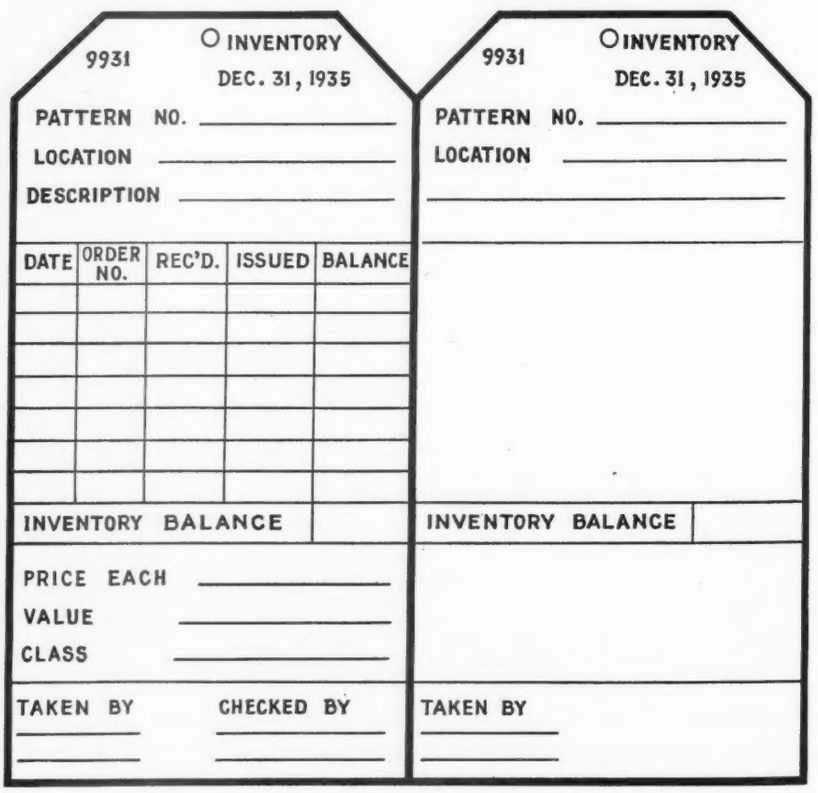

Figure 8. Typical tags used in taking physical inventory

of the inventory. Inventory tags will be issued in the same way to crews assigned the various sections of the storeroom. The count will be entered on each half of the tag as before, and a check stub left with the material. The inventory will be taken from the tags and verified.

Sometimes Overlooked

Among the items likely to be overlooked in taking the inventory are materials in transit, goods on consignment with customers and containers, shipping crates, and other supplies out on loan.

There is also danger of listing as company property similar items on its premises but to which it does not have title.

The inventorying of work in process is a more difficult job than the count of a storeroom, for it is necessary not only to count the materials, but also to estimate the stage of completion and cost. When this work must be done by crews of workmen, foremen, and office help hastily thrown together and given a few hours of drill, the resulting inventory may be very rough indeed.

Most of these difficulties may be avoided by a suitable system of production control and costs. Many companies, for example, maintain a record of work in the shop which serves both as a follow-up record, indicating to what stage of completion the order has progressed at any time, and as a cost card, either for the record of actual labor, material, and burden costs as incurred, or of variances from the standard cost in any one of these items.

Assuming that these cards are kept up to date, or are brought up to date before the inventory is taken, it is a simple matter to go through the job cards, foot the totals of expenditure, and secure an inventory that is far more likely to be accurate than could possibly be expected were the job left to the judgment of temporary crews. This book count may be verified by sampling counts on any percentage of jobs in the shop that may appear advisable.

Less Chance of Error

If the shop material is counted and checked after each departmental transfer, the order records are less likely to be subject to large errors than are the stock records, since the order is usually put through and cleaned up each time, with less possibility of cumulative errors. The only exception to this statement would be in long jobs fed through the shop in a continuous stream.

The annual or semi-annual inventory is the logical occasion for a systematic survey and disposal of obsolescent stock.

CHAPTER SIX

Pricing Materials

THE GENERAL accounting rule is that materials shall be carried in the inventory at cost or market, whichever is lower. Even when the price of a raw material has gone up, so that it would cost more to replace the material than was paid for it, it is conservative accounting practice not to anticipate the profit before it is made. The material may go down again in price before it can be sold. On the other hand, if the material is worth less than it cost, conservative practice indicates the wisdom of reflecting the probable loss in the financial statements.

There are some exceptions to this rule. Land that was bought cheaply and whose value has increased and established itself for a long time is sometimes admitted by bankers to a balance sheet on the basis of an increased appraisal valuation.

In retail stores, where so many hundreds of items are carried and where the price situation is complicated by mark-downs, it is felt by many that the current selling price of the article, including mark-downs if any, is a better measure of the probable cash realization than is the cost, which becomes a practically meaningless figure after one or two mark-downs and seldom has any fixed relation to selling price in any case. The inventory at selling price is easy to take, and may be reduced to cost by applying a reversed average mark-up percentage based on experience and studies.

In manufacturing, however, the general practice is to price at cost. The matter presents no difficulties in a raw material for which the cost remains constant. To the invoiced cost per unit is added the expense for freight and other delivery charges, and with some companies a fixed percentage, based on experience and computed like any other departmental overhead, to cover the handling and storage costs.

Burden correctly applied in this manner is a corresponding relief to subsequent burden charges; the question of whether to allocate burden in this manner or to apply it in the general rate may be settled like any other problem of burden allocation, by deciding whether the increased accuracy of allocation yields control results worth the increased clerical costs.

Two Ways to Price

A slightly more complicated problem is presented when part of a stock has been purchased at one price and part at another. There are several methods of dealing with this case. The two commonest are the cumulative averaging method, and the first-in, first-out method.

In the averaging method, at the time a new lot is received at a new price, the value of the old stock is computed at the old price. The sum of the total values of the old and new lots at their respective costs divided by the total number of parts, old and new, gives a new price that will return the cost of the two lots. No matter how many successive lots of a given article may be averaged in this manner, the total cost will be correctly returned.

Under the first-in, first-out plan, it is assumed that the first lot of a material received, will be the first to be issued. Each successive lot is then priced out at its own cost.

For example, if there should be

200 of a given article on hand, at a price of $1, when a new lot of 500 came in at a price of $1.20, the next order, say for 150 pieces, would be priced out at $1 each. If the next order were for the same quantity, 150 pieces, the first 50 pieces would be priced out at $1, the remaining 100 at $1.20 each, making the cost of the material on the second order $170, or $1.13 each. A third order for 150 pieces would be priced at $1.20 each, and so on until the 500 were exhausted or until the price changed again.

Had the averaging method been used, the combined value of the 200 on hand at the time of the receipt of the new lot, and of the new lot of 500, would have been $200 plus $600 or $800, giving a unit price of $1.14 each.

Averaging, Pro and Con

In favor of the averaging method it may be noted that the price is figured once for all when a lot comes in at a new price, and no attention is needed subsequently to keep the lots separate. There is consequently less likelihood of overlooking or confusing entries. On the other hand, an arithmetical computation must be made every time a lot is received at a new price, and where receipts and price changes are frequent, it might be simpler to keep the lots separate.

With either method, in accordance with the accounting rule mentioned, any serious drop in the price of a material will be taken up in the stock records, and an adjustment carried to profit and loss.

To ascertain at inventory time the current prices on items not recently bought and not quoted by exchanges or recognized trade journals, the purchasing agent may ask for quotations from the usual suppliers.

In pricing irregular lots, by-products, and similar items not properly carried at cost, the method of valuation by bid may be used.

Going through the stock records and adjusting a large number of prices, and carrying the values written off into profit and losses, is a considerable clerical operation. It will not usually be undertaken for small or mixed price changes. In a fluctuating market that may go up or down, the inventory may be corrected for balance-sheet purposes by setting up against it a general reserve account, computed to be sufficient to absorb the loss due to price declines. In this case prices will need to be changed in the stock records. Where substantial price drops have evidently come to stay, as during such years as 1932, the adjustments should be made in the stock records.

Standard Costs

As noted in a previous issue of the Plant Operation Library,[1] the use of standard costs is rapidly increasing. This method of accounting eliminates many of the fluctuations and practical inconsistencies in these older methods of pricing materials. Under this plan, an average cost is figured for each product, after carefully taking into account the price history and price trends of the article.

This cost is not changed for a considerable period, say two years, except in general and serious changes in the price situation. Materials are charged to inventory at standard cost; variances of actual from standard cost, higher or lower, are charged or credited to a material variance account. Issues of material from stores are all at standard cost, greatly simplifying the clerical work of pricing out requisitions. Since a record is kept of all variances from the standard, it is possible at any time to re-figure the inventory at actual cost.

There are so many practical advantages to the standard cost plan, and it seems on the whole so well adapted to the consistent guidance of policy decisions, that it is probable that this method of arriving at cost, while presenting some inconsistencies from the standpoint of a strict application of the "cost or market" rule, will eventually be accepted as standard accounting practice.

The forms shown in Figures 4 and 5 make provision for the entry of the unit price of the material in a column between the "ordered" and "received" columns. Using these forms, the stock record clerk will enter a new unit price in this column only when the price changes, presumably on the cumulative averaging plan described. No provision is made in these forms for extending the value of the item on hand.

Less Clerical Work

Many systems provide for extending the value every time a transaction is entered. In favor of the form shown, which gives price only, are its greater simplicity and reduced clerical work. The dollar value of the stock on hand need be used only occasionally; it can always be figured, quickly and exactly, by extending the last "on hand" balance at the prevailing price. A large number of unnecessary computations, each presenting the possibility of error, are thus eliminated.

Frequently a financial control account of inventory investment is useful, especially where monthly financial statements are used. As receiving slips, material credits, and material requisitions are posted by the clerk to stock records of the type illustrated, it is his duty to enter on these requisitions the unit price of the article. He obtains this price either from the price column just discussed, or from information furnished by the purchasing department as a matter of routine with the receipt of every new purchase. The requisition will usually go next to the cost department, where comptometer operators will extend the value.

One Further Check

After entry to the job or process cost card, if one is used, the priced and extended requisition can now be carried to a control account, showing in dollars only the current investment in each of any designated number of classes of materials. Issues will be credited at dollar value to this account; receipts debited. At the time of closing the books and taking inventory, this financial balance may be reconciled with the physical inventory, providing a further check on the accuracy of the records and the authorized and correctly recorded use of the materials.

[1] "Standard Costs," Charles Reitell, *Factory Management and Maintenance*, May, 1935.

CHAPTER SEVEN

Layout of the Stockroom

PROBABLY the first question in layout is whether stores should be carried at a central point or in local rooms or points adjacent to the place of use. No general rule can be laid down. It is easier to provide adequate supervision and service in a large storeroom than in a very small one. The cost of operating one room is usually less than that of operating several. The degree of service required will depend somewhat on the kind and value of the materials stored. With cheap, bulk materials not likely to be wasted or stolen, and carried in large enough quantities to safeguard against shortages, the necessary supervision may be almost nil.

A second consideration in layout is accessibility. Other things being equal, material should be stored as near as possible to the point of use. Where several departments draw the same materials, no one of them in quantities large enough to justify a separate storeroom, a central depot is usually indicated.

Often it is possible to issue in bulk the materials required by only one department and have them delivered direct to the custody of that department. Whether this is advisable will depend on the balance of the handling cost against the cost and need of supervision and protection. Current, active stock is apt to be better handled by the average foreman than inactive items; the latter should generally be returned to the storeroom at the close of a run.

Less Paperwork

Generally in flow production the tendency is to do away with paperwork and to provide necessary "cushion" stocks at required points in the process, without formal accounting except for materials issued and deliveries of finished products.

Assuming that the question of location of storerooms has been settled in the light of such considerations, the next question is internal arrangement. To make it possible to enforce the rule of sole responsibility, the storeroom should be completely enclosed (by wire mesh if solid walls are not suitable) and locked.

Constant Temperatures

Physical conditions require the same attention in the storeroom as in other parts of the factory. With many types of materials it is important to maintain constant temperature and humidity. Persimmonwood golf club heads, for example, must be maintained in a very dry atmosphere to insure thorough seasoning. Paper stocks will give less trouble in printing, box-making, and the like if maintained at controlled humidities.

With many stocks it is important to insure freshness. This is a matter in the first place of a correct lot size, entailing a specialized application of the depreciation factor. To prevent an accumulation of old stock at the bottom of the bin, one manufacturer of pencils has made special bins for the storage of rubber eraser tips. Stock is put into the top of the bin and removed from the bottom; the bottom slopes forward so that no stock accumulates there.

Storage of oils and similar liquids presents special problems. Storage of inflammable liquids in quantities is often provided in buried and specially vented tanks. For issuing in smaller quantities the common measuring oil dispenser used by garages will effect economies.

The details of storeroom arrangement will depend on the predominant types of materials to be handled. For most small parts and lots of materials, standard unit shelving provides the best accommodation. While wood shelves may serve some purposes, the various makes of steel shelving on the market are generally more durable, flexible, and fireproof, and usually more economical in the long run for continued service.

For many types of heavier materials, the best disposition of space may be an open floor or yard permitting piling on skids or directly on the floor. Other materials, such as long bar or pipe stock, may call for special racks or fixtures.

In general, rows of bins should if possible be placed so as to be lighted from the ends by windows. Aisles should be frequent and wide enough to permit easy handling, say 6 to 8 feet for main aisles down to 2½ feet for side aisles in which only small parts are to be handled. All aisles should rigorously be kept clear. Central station operators have found that the men take greater pride in and better care of their equipment if the dynamo room is kept spick and span. The same is true of storerooms. Apart from the fact than an orderly storeroom saves misplacement, rehandling, and damage to materials, a rigid insistence on order in the storeroom reacts in other directions, such as accuracy. A storekeeper may be judged by the discipline he maintains.

Place for Motion Study

A bit of motion study may be applied with advantage to the management of the storeroom. Materials most often used should be located nearest the window or issuing door and, as far as possible, within the vertical zone from 2 to 5 feet above the floor, which is easiest to reach without undue stooping or reaching.

Use should be made of specialized materials handling equipment wherever the volume and saving justify it. Among such items of equipment likely to be useful in the storeroom are tiering machines and portable elevators, monorails, lift and hand trucks, fixed and portable roller conveyors, either free or driven, elevators—indeed, practically all types of modern materials handling equipment.

Trucks, tractors, and similar large-scale equipment may be called for in large storerooms. In such storerooms the problem of communication may require systematic messenger service or the use of telephones, teletypewriters, telautographs, or pneumatic tube message systems.

Counting and measurement are among the important operations in the average storeroom. Economies may be found in the use of ratio

Standard steel shelving and variable-speed roller conveyor in this stockroom make it possible to handle up to 1,500 orders daily. Average time, 20 minutes after the customer telephoned—7 minutes in emergencies. A stock limit control plan, prompt handling of stock loss cards, and periodic inventory safeguard against back orders—which never top $\frac{4}{10}$ of 1 per cent

scales, recording scales, and similar specialized equipment. A good deal of handling and counting may be eliminated by the use of trays with compartments to hold standard quantities of parts, say 100, or some number convenient for subsequent assembly. The parts are dropped into these compartments as made, automatically positioning and counting them for the next operation. It is also frequently advisable to have purchased parts packaged in quantities that are suitable for assembly purposes.

In counting quantities of parts, a common method is tallying—making a mark for every 10, 100, or other convenient number. As the attention of the man doing the counting may be distracted, the use of a small hand counter is often advisable and may certainly be recommended.

To Find Items

Counting on receipt into stores acts as a check on deliveries. Where counting is automatic at the last production process, or where its reliability is otherwise assured, the double operation may be eliminated.

In finding items in the storeroom, there are two general plans. One is to provide a fixed location for each part or type of part, so that pistons will always be found in one section, cylinder heads in another. This plan serves well where only one basic product is made and parts are always at least approximately in balance. This condition, however, is not the usual one. In most plants, stocks fluctuate considerably, lines increase and decrease in volume seasonally, and the fixed-location plan wastes too much valuable manufacturing space.

City Streets

The more common plan of location is to lay the storeroom out into numbered sections, aisles, and bins and to put stock wherever it may be most convenient. This stock is found by a location number which may be noted on the stock record card or may simply be carried in the stockroom, filed by pattern number, in a card index.

Storeroom sections should be identified as city streets by reference to zero axes at right angles. Should the storeroom be irregular in shape, or should any part of it be otherwise occupied, the numbers or letters that would have applied to these parts will simply be omitted. Once symbolized, the location symbols should be permanent.

CHAPTER EIGHT

Symbolization of Materials

TO AN outsider, such a symbol as *SV2UAP 17-3* looks considerably more formidable than the simple name of the bar stock, fiber board, or other material to which the symbol might apply. When, however, there are many sizes, alloy compositions, and types of bar stock, the symbols become a virtual necessity if confusion and mistakes in identity are to be avoided.

To a foreman who is constantly using one particular type of "hex" rod, the description "$\frac{1}{2}$-in. hex brass rod" is sufficient. This might be filled, in a large storeroom, from any of half a dozen types of stock. Furthermore the symbols, which look so formidable at first sight, are quickly learned, especially as any one employee usually deals only with a limited section of materials.

Symbolization also tends to prevent such mistakes as putting into the same bin two materials that resemble each other closely, such as two bolts of the same size but with different threads.

The general principle in symbolization is to classify the materials on some basis that will coincide with the use to which the classification is to be put. Thus the physical assets of a company will break down into permanent plant (with suitable subclasses) and materials.

Materials may again break down into supplies of various types, such as office supplies and stationery, maintenance supplies and miscella-

neous supplies, and into production materials. The latter, in turn, may be most conveniently identified as parts of a particular pattern or model, or, if used on various models, by type, as bolts, rivets, gears, handles and the like. Material special to one order may be identified by that order number.

Decimal and Mnemonic

Once classes have been developed, they may be symbolized either by the decimal or mnemonic system—or some combination of the two.

The idea of the mnemonic system is to designate each class or sub-class by a letter that as far as possible suggests the name of the class. Thus, *S* for stores, *V* for miscellaneous or variety stores, and so on.

In the decimal system, successive sub-classes are designated by hundreds, tens, units, and so on. Thus 1,000 might designate the general class of "assets" in the accounting system (of which the stores classification may properly be a part), and 1,100 might indicate the general class of stores. A symbol ending in zero is conventionally used to designate a class, and is not applied to an article. The 1,100 class would then leave room for 99 major subdivisions and, using the decimal point, for an indefinite number of secondary subdivisions.

Of the two plans, the mnemonic has the advantage of offering 22 symbols per position instead of the 10 available with the other plan. (Because of the possibility of confusion, *I*, *O*, *Q*, and *U* are usually omitted.) The decimal system, however, usually adapts itself better to the general system of accounts and to use with tabulating machines and is consequently the more widely used of the two.

The great difficulty with symbolization is that, if too complete and orderly a classification is attempted, the symbols become too long and unwieldy. Probably the best plan is to lay out the skeleton for a complete symbolization plan, with room for future expansion, and to apply only those sections that are necessary.

When to Symbolize

Symbolization of materials is not important when the variety of materials is small or when standard bulk materials are already identified by trade names. Systematic identification will save much difficulty and confusion when the product is varied, as machinery, when frequent changes are made in models, and when replacement parts for obsolete models are likely to be called for. In such cases it is a good rule to treat the symbol for each part as permanent. When the part is changed, it is given a new symbol, or a distinguishing subscript is applied to the old one.

CHAPTER NINE

Organization and Personnel

FROM ONE standpoint, the entire work of material procurement and conservation constitutes a single function. Material, however, represents a good deal of money and frequently is easily convertible into money in unauthorized ways. In its procurement, there are exceptional temptations to, and chances for, irregularities. For these reasons, it is usually considered advisable to separate the functions so that one department will automatically act as a check on another.

Also, as indicated at the outset, the function of material procurement is closely related to, and is being more and more considered a part of, the general problem of production scheduling.

To meet this requirement, as well as to provide a check on operation, a typical organization of the material-procurement departments would place the purchasing agent under the general manager or sometimes, where the work is especially important, directly under the president, sometimes with the title of vice-president. The receiving department may report to the purchasing agent or to the factory manager or superintendent. The chief storekeeper will usually report to the factory manager, while the stock record department will be a division of the production control department. The traffic manager may report to the purchasing agent if his work is mainly with incoming shipments, to the sales manager if the reverse is true, or be an independent executive under the general manager if the work is more or less evenly divided or affects several departments.

Bonus in the Storeroom

In the practical management of storeroom employees, the problems are much the same as in dealing with any other employees. Various plans of bonus and other production incentive have been tried and are applicable to situations with large element of routine.

For most situations, straight daywork with good supervision is probably as effective a payment plan as any. Storage is essentially a maintenance and service job rather than production, and recognition by the supervisor of a well-kept section and of prompt and errorless service, with instruction and discipline, if necessary, for poor work, will do as much as money incentives to secure good performance, particularly if the incentive is complex or not accurately adjusted to effort and to quality of output.

There is a certain type of man who is just fitted for stockroom work—one preferring routine jobs requiring little initiative, who is precise in habit and individualistic rather than gregarious in attitude. Give such a man a section of the storeroom for which he is solely responsible, teach him his work, inspect it, furnish him with bin tags or other ways of testing his own work, give him praise or blame as deserved, and you may be pretty sure of dependable records in that section at least.

When Loads Shift

Storeroom operating costs will be reduced if the chief storekeeper understands something of scheduling principles. The work in the storeroom is often irregular and intermittent. Also, the load shifts from one section to another as seasonal

peaks come and go in the various lines.

These shifts of loads are not usually as noticeable as in the direct production departments, and, unless the chief storekeeper has given some study to the amount of work in the various sections, there may be several men for whom there is not enough work to occupy even half their time, but who naturally hesitate to report the fact and manage to seem busy. Such men may be assigned temporarily to part-time work in the active sections, or may be employed on various jobs of rearranging stock and shelving, repairs, and other work of like nature. Sometimes small production jobs can be used as fill-ins. Output standards are as useful here as anywhere else, and may be set by the same methods of time and motion study.

CHAPTER TEN

Measures of Storeroom Performance

DUE TO the close tie-in between production, purchasing, and storeroom performance, it may not be possible to reduce material-procurement activities to any finally conclusive denominator. The following, however, are some of the more important measures of results in this field of modern management:

Inventory turnover. It may be defined, either for a department or for the business as a whole, as the ratio of sales or production at cost for a period, usually a year, to the average inventory at cost during the period. While the general policy decisions affecting this factor are usually made outside the material-procurement departments, even the humblest stockroom man may, if he understands its importance, contribute to a low turnover by watching to use up short ends of stock, to dispose of discontinued items which may be used on current jobs, etc.

Continuity of service. When the factory shuts down for half a day because somebody forgot to order in time, made a mistake in count, or took a chance in setting minimum limits, it is worth while to find out who made the mistake and to take steps to prevent its recurrence. This factor may be hard to measure, since the cost of a broken promise to a customer may be quite beyond computation. It should be possible, however, to establish certain indexes of service, such as the number of delays traceable to lack of stock or mistakes in filling requisitions, or the monthly expenditure for express shipments, excess costs of warehouse purchases, or similar factors not directly controlled by the supply departments and tending to vary with the effectiveness of materials service.

Cost of operating the department. Under modern budgeting methods some degree of accuracy is possible here. Studies will have been made of the labor and other operating costs of the department, and of the variation of these costs with volume. The ability of the storekeeper to meet or better these costs should afford a fair measure of his ability as a manager.

A measure particularly applicable to the purchasing department is the *price paid for purchases during a given month compared with the average price of the commodity as indicated by market quotations.* This index should not be used without some check-up on the dependability of the quality and service obtained, otherwise it is likely to exaggerate one of the commonest faults of purchasing agents—the tendency to buy on price at the expense of the long-run cost of the purchase as measured in economy in manufacturing, quality, dependability, and continuity of supply, and similar intangible but important factors.

It cannot be too strongly emphasized that dependable material supply is the foundation of good production control. It is perhaps not without reason that the decline in the relative importance of storekeeping, which has gradually become noticeable over the past decade, has coincided with the growth of accuracy in operating standards. When it is possible, for example, to budget sales dependably in order to manufacture to definite budgets, costs, and schedules, or when marketing customs make it possible to start manufacturing after the order is received, the need for reserve stocks dwindles.

Even with this improvement of control, which is eliminating the huge inventories once considered necessary, the storeroom will continue to play an important part in those industries where the economies of lot production indicate a stock-limit control. And an understanding of the principles of inventory control is not less vital to business success because a part of this control is transferred to other than the materials handling departments.

Supplementary *Factory* Reading

Stockroom on Wheels ..... ***Lewis K. Urquhart***
AUGUST, 1930

Case of Management vs. Excessive Inventories ..... ***H. Soper***
SEPTEMBER, 1930

Graphic Inventory Control ..... ***E. J. Keller***
NOVEMBER, 1930

How About Your Stockroom? ..... ***A. F. Landsea***
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Normal Stock Method ..... ***William F. Burke***
JULY, 1934

QUALITY CONTROL

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CHAPTER ONE

The Objective of Quality Control

INSPECTION serves two general purposes. It is necessary, first, in the interest of the customer, who might otherwise receive unsatisfactory goods. Second, like the thermostat which turns the heat off and on as it is needed, or like the sprinkler head which opens when there is a blaze, an inspection system indicates points in the factory processes at which some control is failing to act and correction is called for.

The purpose of inspection is thus in a broad sense the control of variables. Any analysis of factory inspection may therefore well start with a discussion of some of the more common of these variable elements. When they are known, the problem of their control is usually more than half solved.

First let us define the objective to be attained by control. The customer may want a great many possible qualities in his purchase; any classification of these needs would have to be very general. Among the qualities likely to appeal to the customer are low cost or a large value for the money relative to what may be obtained elsewhere; style or appearance, or qualities pleasing to the senses or to the customer's tastes; serviceability. Serviceability may in turn depend upon a multitude of qualities—strength or purity of the materials used, precision of fit, correct proportioning and design of working parts, ability to resist deterioration, electrical conductivity, permeability or imperviousness to liquids, or any one of thousands of other specific qualities.

The first step in efficient quality control is a correct interpretation of customers' wants. And one common mistake in quality control is a selling mistake, the attempt to serve customers whose wants are incompatible.

Serving Two Masters

A manufacturer of fine laboratory furniture, for example, thought once to keep his force busy during a dull season in the sale of equipment to college and research laboratories, by turning his factory to the making of manual training desks, a product in which the tolerances and finish are customarily of a lower order. The manufacturer had all the necessary equipment, and his men were skilled craftsmen who could easily turn their hand to the production of virtually anything made of wood.

Markets in both cases were with schools.

On paper the plan was logical, but he found that if he put his men on the new product he must reconcile himself to one of two incompatible alternatives. Either he must produce manual training desks of a quality higher than was needed or would be paid for, or he must disorganize the habits of careful workmanship which had won a name for his major product. The manufacturer discontinued the new product. It would have been necessary to build up an almost completely new organization to have carried on the two lines with both commercial and technical success. To have done this would have left the original problem, greater continuity of employment for the present organization, unsolved.

High Cost of Cheap Labor

Recently a manufacturer investigated the possibilities of locating a branch factory in a district where one of the inducements was low-priced labor. Although this manufacturer makes low-priced, competitive lines, his emphasis traditionally has been on top-quality, well-styled merchandise. He concluded that the cheap labor would find it hard to adapt itself to frequent style changes, and that it would be difficult to educate and retain a force keyed to the company's customary standards of quality.

He might, by raising wages, attract a higher class of operative at a price perhaps slightly below what he would have to pay at his present location, but to do so would arouse the antagonism of other manufacturers in the locality. After weighing these facts, he decided against the new location in spite of attractive bonuses and other inducements.

On the other hand, the experience of a manufacturer who, to meet shifts in customer taste, decided to grade his product upward, illuminates the difficulties of any departure from established quality standards.

The company's steel buyer had been accustomed to picking up job lots of stamping, quite all right for a cheap product but of variable hardness and gage. The superintendent and the entire working force were keyed to fast, slap-dash production. Dies were cheaply made and much worn. With the old product it did not matter if an extra hole or two, required with one model but unnecessary on another, were punched in the supporting arms. Inspection was nominal; the product was sold on a price basis to customers who frequently required it for temporary use and who, knowing that they did not pay much, did not expect a long life from it.

▼

Interlocked with quality are cost, selling price, volume of sales, and net profit. These five fundamentals are uppermost now, as always, in our industrial economy

▲

When clear signs appeared that customer tastes were being educated by competitors to higher levels, the company decided that it must follow suit. An inspector was hired, and the production organization was duly impressed with the importance of the occasion. The company's salesmen were called in, given a pep talk on the new possibilities and a shiny new line of samples, and sent forth to make enthusiastic promises to customers.

Orders began to come in. Complaints followed the orders. The inspector, an ex-foreman, was galvanized into a rigid resolution to apply literally the watchword, "They shall not pass."

Then came a period of exasperating interferences with production, mounting costs, delayed orders. The inspector was doing his work. At last the pressure became more than the president could stand. There was no official announcement of change of front, but orders were passed over the inspector's condemnation. Salesmen, irritated at delays and hounded by customers, looked over defective lots and said, "Oh, let them go," and the inspector, sensing the lack of support, dropped back to the complaisant and nominal inspection that was the only possible thing under the circumstances.

Every now and then, a customer gets a particularly sour lot of goods and the salesman explodes at the home office. There are profuse explanations of the unique combination of causes for the trouble in that particular case. The goods are replaced or repaired. A new quality equilibrium has been reached, slightly above the original level but far below the previous intention. Possibly this intention was itself too high; it remains to be seen whether or not a market equilibrium has been reached.

The determination of what the customer wants and is willing to pay for is primarily a marketing responsibility. The manufacturer of electric ranges who dropped from a $110 product to a $75 unit made a wise move; there was only an occasional purchaser for the top-quality range, whereas there were many for the low-priced but serviceable unit. So in each case it is primarily a selling decision as to which particular niche in the quality scale promises the best, most profitable, and permanent market.

One Quality Level

Usually, for reasons similar to those governing in the examples cited, best results are secured when the whole organization is adjusted to one general quality level. In large companies, such as General Motors, which cater to the entire gamut of quality demands, it is noticeable that both production and selling of a given quality range of cars are handled by self-contained divisions.

The analysis of the quality specifications does not end, of course, with the opinions and investigations of the sales division of the business. Impracticable demands, or demands impracticable at the price, may be made. There must be consultation and compromise between sales, engineering, and production.

CHAPTER TWO

Inspection Specifications

SPECIFICATION of the standards to which the product is to be held is closely related to the effectiveness of quality control. In what terms is quality defined? One of the simplest types of quality is conformity to dimensions. But how close a conformity is necessary? On the blueprint it is easy to indicate the diameter of the shaft as one inch, but probably only one in a million, if even that many, of the shafts actually produced will be precisely one inch in diameter throughout their length. The others will be thicker or thinner, out of round, out of line, tapered, or otherwise variable to some extent throughout their length. Dimensions, in practice, will be specified by tolerances—the ideal dimension, plus or minus a permissible variation which may vary from zero up.

Measuring Color

Color, under one fairly widely used system, the Munsell system, is specified by three characteristics—*hue* (the kind of color, as green, blue, violet), *value* (the lightness or darkness of the hue), and *intensity* (the degree of purity of the color, or of admixture with white, black, or intermediate shades of neutral grey).

Another and more precise method of specifying a color is by measuring the intensity of the spectroscopic lines, when illuminated by a constant light source. Exact color measurements become more and more widely used, not only in obvious applications to dyed and colored fabrics, but as indicating the permissible variations in the color of tobaccos, for example, or of lard or animal fats, or of oils.

How would a taste or odor be specified? In general, the determination of quality in terms of these qualities is left to the trained judgment of expert tasters or inspectors. A scale has, however, been proposed for the specification of odors.

In many trades, standard grades and specifications have been adopted by trade associations or trade custom. "A Survey of the Terms Used in Designating the Quality of Goods," published in 1935 by the Consumers' Advisory Board of the National Recovery Administration, gives a concise summary of the standard grades used in about forty products and raw materials.

Basis of Specification

In general, specification may be either on the basis of process, composition, dimension, etc., or on the basis of performance. Thus cocoa is specified by country of origin—Ceylon, Java, and Trinidad, for example, falling in the first grade, Jamaica fermented in the third, Jamaica ordinary in the eighth grade. Metals may be specified on the basis of alloy composition and heat treatment—a specification by kind—or on the basis of tensile strength, ductility, fatigue resistance, and so on—a specification by performance.

Assume that the quality has been decided on, material specifications have been written, or an approved sample is in the hands of the manufacturing department. A process layout is in order.

Here, in the specification of the details of raw materials and processes, is the next step in quality control. First, of course, is the decision as to materials. What kind of finish is needed to meet the particular service conditions, as exposure to weather or indoor use? Or, if a supporting arm, shall it be cast iron, die-cast zinc, a steel stamping, an alloy steel forging, or some other material?

Second, a choice must be made as to process, and processes are especially interesting from the standpoint of controllability. The supporting arm cast in sand may vary a tenth of an inch or more either way from the specified precise dimension. The forging may be held to a hundredth. If bearings are required, they may be drilled, reamed, broached, ground, or lapped to successively closer degrees of control.

Precision at a Price

Generally, although not necessarily, the finer the fit, the greater the cost. In the exceptions to this statement, the possibility of securing a better quality without increase of cost, lie many manufacturing opportunities for the well-informed cost reduction and designing engineer. The automobile manufacturing industry is one continuing testimonial to the possibilities of intelligent design for precision at a price.

In most cases, however, a choice must be made at this point on the basis of comparative costs. In this choice there are commonly three important factors—cost of process, cost

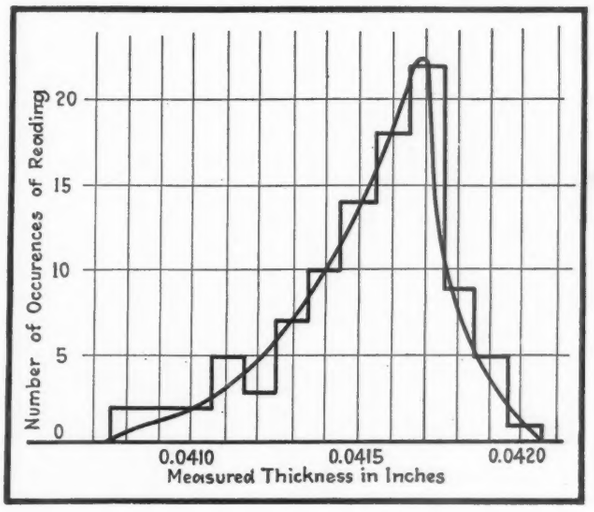

Figure 1. One hundred measurements of thickness of a steel strip arranged according to frequency of occurrence

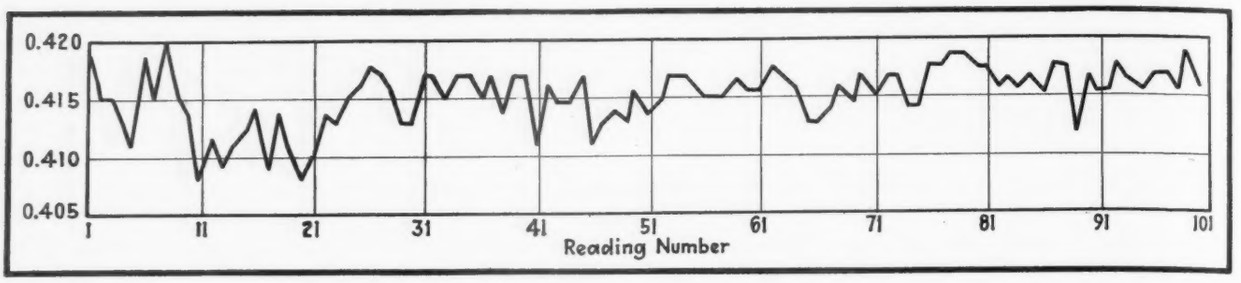

Figure 2. Successive measurements of thickness of a steel strip

of rejects, and value of control in terms of added service, price, or marketability.

The accuracy of a machine may depend on hundreds of factors. The machine itself may inherit the imperfections of previous machines or processes; the bed of the drill press, for example, may not be square with the axis of the drill. Or the process may produce tensions that distort the work, the tool, or the machine. Grinding is inherently subject to finer control than ordinary drilling, because of the much smaller amount of metal removed by the abrasive particles than by the lip of the drill.

Enter the Human Equation

Other factors capable of causing variation may be play in the bearings or other working parts, or wear. To these variables must be added the many variables of the human operator and those due to the material, which may not be homogeneous or may be subject to internal stresses that cause distortion after a cutting operation.

In general, variations in any process result from the interaction of these variables; if the cause of the variation can be found and corrected, the variation will disappear. Taking up the play in the bearings will improve accuracy, for example. But after all practicable adjustments and corrections have been made, there still generally remain with any particular machine a number of variables that cannot be controlled. These variables may occur in all sorts of combinations. The eccentricity of the drill point may be neutralized by an accidentally offsetting eccentricity in the setting of the jig on the bedplate. On the other hand, the most unfavorable combination is equally likely to happen.

If the most unfavorable variation at the process is within the tolerances compatible with the desired service of the product, the process will require no inspection after it is correctly set up.

Assuming that no constant cause is operating in the process, the variations from the desired standard tend to distribute themselves about the standard somewhat as in Figure 1, which shows the number of times each reading occurred in a series of 100 readings (with a worn micrometer) of the thickness of a thin strip of steel. With a larger number of readings, they would normally tend to distribute themselves in a smooth curve, more or less symmetrical with reference to the vertical axis, which indicates the most probable reading. Variations caused by uncontrollable residues of error in a machine would tend to follow the same distribution.

What Tolerances?

If we assume a dimension of 0.0416 ± 0.0005, only 6 pieces out of a lot of 100, which were produced to the dimensions indicated in Figure 1, would be outside the tolerances. Had the specification been 0.0416 ± 0.0002, the rejections would have constituted 27 per cent. With tolerances of ± 0.0001, the rejections would have been 46 per cent.

At some point in the scale of increasing demands for exactness, it probably would have proved economical to introduce a more exact process of manufacture; the cost of the rejections would have overbalanced the saving by using the cheaper machine. Evidently it will be economical in practically all cases to make the tolerance as large as is compatible with the service to be performed by the product, the importance of precise fit, color, composition, or other quality, and the price the customer is willing to pay for it.

Getting the "Feel" of the "Mike"

If the readings in Table I are plotted in consecutive order as they were originally taken, as in Figure 2, it will be noticed that they start out with a wide variation and then steady down to a range of 0.0415 to 0.0417, with only occasional variations. The operator is getting the "feel" of the micrometer and, in spite of its inaccuracy, would probably with further practice get almost uniform (although, in this case, not necessarily correct) readings.

Variables of the operator form another class of elements that must be dealt with in the attempt to secure quality. Among these variables are:

1. *Degree of understanding of the task or objective.* The operator may aim at finish when accuracy of dimension is required, may misread instructions, and so on.

2. *Muscular coordination, accurate eyesight, fineness of touch,* or other

Table I. Micrometer Readings of Thickness, Showing Chance Variation in Reading

Thickness in inches	*Number of readings secured*
.0408	2
.0409	2
.0410	2
.0411	5
.0412	3
.0413	7
.0414	10
.0415	14
.0416	18
.0417	22
.0418	9
.0419	5
.0420	1
Total.....	100

characteristics of the body as an operating mechanism. In part these qualities are native; in part, acquired skills. Coordination and precision vary with physical condition; the operator will have off days. After even a short absence from work, as over the week-end, skill will in some measure have to be relearned.

3. *Attention.* On monotonous work the attention is often divided between the work and day dreaming, or outside distractions; habit and rhythm usually control the operation sufficiently, but slips occur.

4. *Attitude.* There would be no more economical first inspection than by a conscientious operator who would repair or reject work that did not meet standard. Frequent departures from this ideal attitude result, unfortunately, from indifference, resentment, or cupidity. And even apart from such questions of attitude, there is the very great possibility of occasional lapses of attention.

In general, the larger the extent to which manual controls enter into processes, the more nearly complete will be the inspection required. An automatic punch press, once it is correctly set and supplied with uniform material, will produce blanks or formed pieces by the thousand, within tolerances determined by the residual variables of the machine, which will never be exceeded. Even the most careful operator, however, will make an occasional bad slip, whereas with inexperienced, unskilled, or transient labor the most unfavorable combination of variances may be very bad indeed.

CHAPTER THREE

Where and What to Inspect

SYSTEMATIC study of operating results along lines indicated in Figures 1 and 2 and the corresponding tables may yield useful results, as indicating the causes at work to produce variations from standard. It is not necessary to draw the curves in all cases, except to visualize the trend of the data.

Were the dimensions of parts made by an automatic machine or a die to be plotted consecutively as in Figure 3 (or say for every hundreth part) one would expect to find a slow constant increase in the diameter, for instance, as the tool wore. Superimposed on this ascending diagonal line would be the chance variations, over and under, due to residual variations in the material, to looseness of bearings, vibrations, and other uncontrollable causes. In Figure 3, tolerances have been assumed; theoretically the machine would produce 1,000 parts before the combination of the constant rate of change in the dimension, with the uncontrollable residual variations, would produce unusable parts.

Had the data been plotted for variation with depth of bore in the composition of test borings of a brass ingot from top to bottom, the constant tendency would not have been a straight line, but a similar combination of a defined variation with a random combination of miscellaneous variations.

Shewhart[1] suggests the use of graphs of similar type to indicate danger points in factory process control. If from week to week, or at other regular intervals, measurements of lots or of samples are charted to show the deviation from standard of size (or other measurement or comparison), any tendency to increase the deviation from standard, either by a shifting to another measurement, as with the worn tool, or by an increasing irregularity, as with an operator who is growing careless or a working force that is being diluted by unskilled operators, will become clearly apparent, and usually before the trouble has increased to the point where it is serious. Such danger signals can then be traced, by isolation, to the point at which the trouble is arising.

Evidently one point in the securing of an adequate inspectional control is the selection of the points at which the variation is likely to occur. Indeed, in the variation of the die or tool due to wear, the obvious point of inspection would be at the tool, plus some sort of spot check at intervals as a precaution against sudden departures from standard such as might be caused by a shift in the tool setting, the sudden chipping of the tool, or some similar irregular factor, possible but unusual.

Where Failure Is Costly

Points of inspection will also be selected with reference to the points at which the results of previous operations would be concealed. Furniture, for instance, will have a thorough check-over in the white, before being painted. Often several

[1] *Economic Control of Quality of Manufactured Product,* by W. A. Shewhart, Van Nostrand, 1931, p. 275.

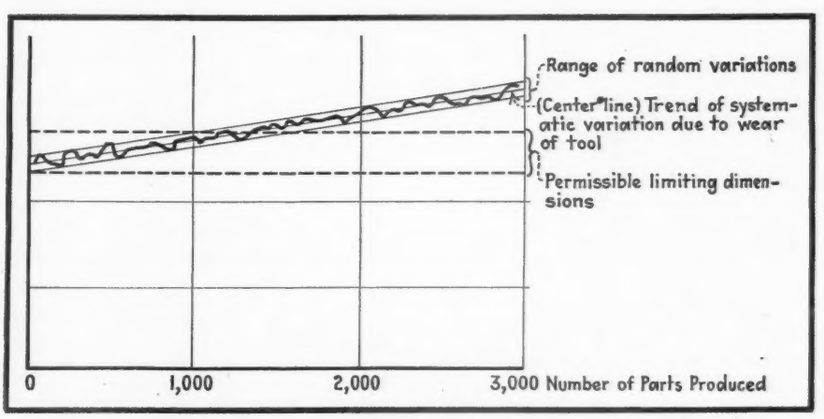

Figure 3. Were dimensions of parts made by an automatic machine to be plotted consecutively, one would expect to find a slow constant increase in diameter—for instance, as the tool wore

previous operations can be checked at one time by a suitable selection of inspection points.

Another rule for the selection of inspection points is that work or parts must usually be inspected where the responsibility is transferred to another department. This inspection may in some cases be performed by the operator in the incoming department who first handles the transferred lot; in other cases, and with somewhat greater accuracy, the work will pass through a regular inspection point before it is accepted.

Still another rule is to inspect at points where failure would be costly.

CHAPTER FOUR

Inspection by Sampling

PROPER selection of the inspection points will reduce the cost of control without reducing its effectiveness. A further reduction of cost may be had by the use of a sample of the right proportions. Here again we may distinguish between casual effects that may be traced, and accidental or random variations. Thus the inspection of the first and last piece produced by an automatic lathe or punch press would be sufficient to indicate whether systematic causes had brought about a change in dimensions.

The question of the size of sample necessary to insure a reasonable probability of being representative of the lot, involves one of the most interesting mathematical analyses in connection with industrial work, made in recent years. This analysis[1] is beyond the scope of this paper. A simple illustration of the theory of sampling may be given, however.

Referring to Table II, what size of sample would be necessary in order that it might, with reasonable probability, include at least one of the six pieces that would be classed as over or undersize if the specifications called for a thickness of $0.0416 = 0.0005$?[2] The computation of the probability in this simple case follows formulas available in most college algebras.[3]

A 200-to-1 Shot

Figure 4 gives the probability, for various samples of from 1 to 50 pieces, that the sample will contain one or more of the six defective pieces. In the case illustrated, if the material were to be used by the organization and the occasional passage of a defective part were not a matter of serious moment, a 35 per cent inspection would give about 1 chance in 15 of passing a lot containing six defective parts. By increasing the size of the sample to 40 per cent, the chance would be reduced to slightly over 1 in 200. For a sample of 50 per cent, the chance of missing all six defective parts would be 0.000326, or practically nil.

Computation of sample size for a lot that might contain anywhere from 1 to 6 defective pieces per 100 presents a somewhat more involved problem, but one capable of solution. The mathematics of sampling is still somewhat involved for the average shop; once tables have been worked out, as they have been by a few organizations, it is possible to use them as one would a slide rule, without bothering about the laborious mathematics behind them. With such tables available, the cost of inspection to obtain a given degree of control will be substantially reduced.

The use of probability tables is necessary only in dealing with the purely chance variations in process; any systematic cause, such as increase in size because of the wear of a tool or die, could be handled by a schedule calling for the resetting, regrinding, or replacement of the tool at intervals short enough so that the wear would never exceed the permissible tolerances.

If sufficiently accurate processes were used so that all the parts produced fell within the tolerances (Figure 1), then both in this case and in that of the controlled constant wear just considered, inspection would be unnecessary except in a precautionary way, to prevent the continued production of scrap due to some sudden and unexpected cause such as a displacement of the tool setting by an abnormally hard spot in the material.

In taking a sample, care must be used to obtain a representative one. A boy working at a drill press found that the inspector made only a casual examination of a few pieces picked up from the top. The pieces then went into stock and the boy, a temporary employee, was paid his piece rate. He was a smart lad and it did not take him long to sense an opportunity. It was only by chance that a lot went directly into production instead of into stores, and it was discovered that the boy had drilled the top layer of every box with great care, but had touched none of the pieces beneath.

In sampling coal for a test of contained heat units, ash, volatiles, and so on, the accepted practice calls for

Table II. Micrometer Readings in Order Taken

.0419	.0410	.0411	.0416	.0418
.0415	.0414	.0416	.0418	.0416
.0415	.0413	.0415	.0417	.0417
.0412	.0415	.0415	.0416	.0416
.0411	.0416	.0417	.0413	.0417
.0419	.0418	.0411	.0413	.0416
.0415	.0417	.0413	.0414	.0418
.0420	.0416	.0414	.0416	.0418
.0415	.0413	.0413	.0415	.0412
.0414	.0413	.0416	.0417	.0417
.0408	.0417	.0414	.0415	.0416
.0412	.0417	.0415	.0417	.0416
.0409	.0415	.0417	.0417	.0418
.0411	.0417	.0417	.0414	.0417
.0410	.0417	.0416	.0414	.0416
.0414	.0415	.0415	.0418	.0417
.0409	.0417	.0415	.0418	.0417
.0414	.0414	.0416	.0419	.0416
.0411	.0417	.0417	.0419	.0419
.0408	.0417	.0416	.0418	.0416

[1] See Shewhart, *Economic Control of Quality of Manufactured Product*, Van Nostrand, 1931.

[2] Presumably, if such a sample revealed no defective parts, the lot would be passed without further inspection; if one or more defects were found, either the whole lot or a larger sample of it would be re-inspected.

[3] The number of possible combinations, all equally probable, of 100 parts in lots of 5 will be $\frac{n!}{r! \times (n-r)!}$ where n is the total number of parts, r the number in the sample. Or, (1) $\frac{100!}{5! \times 95!}$ The number of possible combinations of the 94 *good* parts only (that is, the combinations in which none of the defective parts is drawn) is (2) $\frac{94!}{5! \times 89!}$. Dividing (2) by (1) gives the figures on which Figure 4 is based.

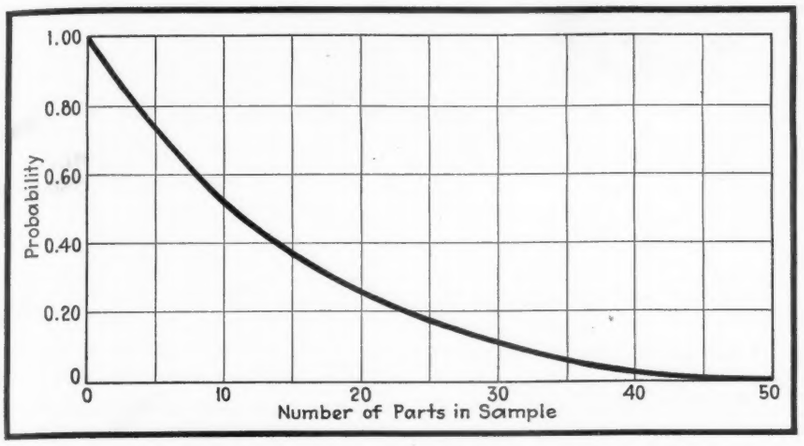

Figure 4. Probability that a sample will contain one or more defective parts

the drawing of a sample by a process of successive quartering, which insures a representative mixture. In other cases, the parts or material will be mixed; a sample will then be drawn at random.

Batch and Bulk Materials

With materials made in batches and by the nature of the process subject to thorough mixture, as a cropped ingot after rolling or a batch of paper, a small number of samples may serve. Again, the nature of the causes of possible variations would have to be studied; the top of the ingot, for example, would usually be of lower quality than the bottom; an emulsion of miscible oils and water might vary considerably in proportions of oils and water if drawn out slowly through a faucet at the bottom of the container.

Samples of an operator's work will usually be taken at random intervals after the work is finished and without the operator's knowledge.

It is usually advisable with some exceptions, such as bulk materials, to submit the product to a 100 per cent final inspection before delivery to the customer. At this time appearance, satisfactory performance of a motor or other apparatus under test, omissions or variations from specifications, and other general tests may be made, frequently simultaneously and often as an incident to the final assembly, running-in, boxing, weighing, or packing of the product.

CHAPTER FIVE

Inspecting the Inspector's Work

AMONG the processes to be inspected is the work of the inspectors. Rules for selection of samples and of sampling points do not differ in principle from those just discussed. Among the possible systematic causes of variation are the wearing of gages, the fading or discoloration of color comparison samples, or the mutilation of outlines of samples and similar tendency toward any variation of measuring tools. To guard against such a drift in standards, good practice is to maintain master standards which are carefully preserved from deteriorating influences and are used only at considerable intervals to verify the accuracy of the working gages.

For dimension gages it would be standard practice to make up a set of master gages with which the working gages are checked at intervals dependent upon the rate of wear. The working gages might be held to a tolerance 10 per cent of that permitted for the product. When the working gage varied by more than the prescribed tolerance, it would be retired from service, either to be scrapped or repaired. The anvils or points of a worn gage might, for example, be chromium plated and reground to dimensions, or might (where a series of closely stepped dimensions were in use) be ground to the next larger dimension. When the master gages were worn past the 10 per cent permitted tolerances, they might be used as working gages.

Master gages, in turn, would be compared with a precision gage such as the Johansson blocks. The U. S. Bureau of Standards supplies a varied and valuable service in the calibration of measuring instruments and standards, such as electrical measuring instruments, measures of density, color, and the like.

In a large organization it is often advisable to equip one portion of the inspection department quarters for the systematic testing of gages and measuring instruments. For accuracy such work usually requires closely controlled standard conditions, rigid and non-vibrating foundations, uniform temperatures, delicate apparatus that must be protected from dust, fumes, or handling, solutions that must not be contaminated, protection from light or moisture, or other definite controls that can hardly be satisfactorily secured without special provision.

In the inspection of the work of inspectors for chance causes, such as slips of attention or carelessness, the usual method is a random reinspection of a certain portion of the work, samples being taken after inspection without advance notice. Records will be kept of the number of errors chargeable to each inspector, giving a basis for selection and promotion as well as for special attention, training, or transfer if work is not up to standard.

Quality Standards Fluctuate

Frequently an inspector will fall into systematic or persistent errors, due to some misunderstanding of specifications, some conflict of personal ideas, prejudices, or habitual standards with the standards presumed to be employed. A common error is a gradual shift upward of

the inspector's standards of quality, until rejections are made of product having slight defects or variances that in no way make it unfit for the purposes for which it is to be used. This difficulty will be slight where definite specifications and tolerances can be supplied.

But in nearly every shop the actual standard of quality, in such intangibles as finish and appearance, and even to some extent in precision of dimensions, is far from an entirely fixed quantity. This standard fluctuates to some extent with the pressure of work in the house; even customers will be satisfied with a slightly lower quality if they feel they must choose between quality and delivery. A new source of material, which may be equally as good as the old but different in minor respects, is likely to entail a lowering of quality until the shop has accustomed itself to handling it. Fluctuations in labor turnover, trouble with a machine, or just a let-down on the part of some responsible executive, or of a department or the shop as a whole, is sufficient to account for fairly substantial fluctuations in the quality of the product.

Inspectors respond to such variations and tend to adjust themselves to the general consensus, unless standards are actively upheld by the head of the department and in turn by the general management. One of the more important of the problems of inspection is this day-to-day adjustment of quality standards to such changes, either by accommodating them to a degree, if it seems advisable, or by taking active measures to combat the drift.

CHAPTER SIX

Tools of Inspection

AN ATTEMPT to catalog equipment for inspection and testing would include for one application or another a large share of the instruments and measuring devices known to science. Furthermore, a large proportion of those in more common use are well known in the industries in which they are employed. Suggestions may sometimes be carried over from one application to another, however, and a few of the more generally applicable methods of measuring and testing are named below.

Quality and Performance

A first step is to define qualities that affect performance and to establish a measure of the relation between the quality and the performance. Thus an automobile crankshaft may be in static balance but out of balance at the speed at which it will operate; dynamic balancing is necessary for good performance. "Thixotropy" — the ability of a colloidal or gelatinous substance to liquify on agitation, returning to a solid or "jelled" condition after a period of rest—is an illustration of the distinction of a measurable property that promises to be of use in judging the freshness of foods.[1]

Another illustration of the importance of correct correlation of specific characteristics with performance is furnished by the case of the manufacturer of paper box board, who found that stiffness of the paper stock was a better measure of the performance of the corrugated board under load than was its resistance to tearing, as measured by the commonly employed bursting test for paper.

One of the common methods of refining a measurement is by substituting a mechanical for a muscular or human measurement. For example, the micrometer with a friction or ratchet release, which assures a constant pressure between the anvils, will give more uniform measurements than the older type which depends on the "feel" of the operator. In the same way the use of temperature controls in place of color in the heat treatment of steels, the use of the spectro-photometer in analyzing and specifying colors, and many similar examples might be given.

New Instruments

The use of mechanical or other multiplying devices is another method of wide application. Examples are the use of a beam of light from a small mounted mirror to indicate small rotational changes, the use of pointers to multiply readings of very small dimensional differences in thickness or diameter, employed in many modern gages and measuring instruments, and the amplification of very slight electric currents by the vacuum grid tube.

Backlash presents a common problem in the use of multiplying and measuring devices such as the screw of a micrometer or the recording pen of a thermometer. It may be controlled by a constant opposing tension, spring actuated, or by similar means.

Many of the most interesting methods of examination utilize newly discovered properties, new instruments, and other recent discoveries. An interesting case in point is the examination by polarized light of models of gears, structural members, and the like, for strain. The model is constructed of transparent plastic or similar materials; when it is stressed as the working part, the gear tooth, or keyway would be stressed, differences in refracting power develop in the material, which show up as rings or lines in the stressed material when viewed by polarized light.

Use of the X-ray for the examination of castings for flaws is another unusual application of a scientific process. The stroboscope is another former scientific toy that has been put to good use in the development of the automobile and other fast-moving machinery. The moving member is viewed by the light of a neon tube which is lighted and extinguished many times a second by an alternating current. When the frequency of the current coincides with the frequency of revolution or other cyclic action of the part being studied, the moving part, seen only

[1] *Industrial Bulletin* of Arthur D. Little, Feb. 1935.

at those instants in which it is in the same position in its cycle, will appear to be at rest or to move very slowly, if slightly, out of synchronism.

Precisely what is happening in a vibrating shaft or spurting oil jet may thus be learned. The slow-motion camera has been used with success for the similar analysis of defects in moving machinery, defects that would not reveal themselves were the machinery operated at a slower, observable speed, since torsional, centrifugal, or other strains would then be different.

The study of noise in moving machinery by means of the microphone, using radio amplifiers and a mirror system to show the shape and amplitude of the sound waves produced, has yielded interesting results in automobile design.

New Applications

The phototube has already indicated its utility for the measurement of light. It has been applied to the grading of tobacco, the sorting of beans, and the control of the color of soap. One of the most recent applications, of which the first installations have now been in successful commercial use for about a year, is a photo-electric egg tester. It automatically grades the condition and freshness of the egg by reference to such factors, measured by the machine, as the roundness of the yolk. It will also sort eggs by color of shell, is claimed to be much faster and more accurate than a human operator.

A $300 microscope is saving about $50,000 a year for a manufacturer of woolen fabrics for men's clothing.

Fiber size varies widely in wool from different sources. Wool that is too fine is objectionable; so is wool that is too coarse. Hence, the purchasing agent for this firm uses his microscope, when buying wool, to make sure that the fibers are of the desired size.

When NRA codes were drawn up for the canning industry minimum sugar content was specified for canned fruit syrups. Existing equipment was not suitable for the conditions under which it was now necessary to make quick determinations of sugar content. At the same time, failure to meet specifications would make a canner liable to severe penalties.

Appealed to in this emergency, a manufacturer of optical instruments soon designed a simple, portable device with which it is possible to check sugar content of a syrup in a moment's time, right at the kettle.

Many testing devices are arranged to submit the material to accelerated service tests. Rubber belting, paper, leather, fabrics, wire or strips of metal such as springs are subjected to long-continued repeated bending, the number of bends being recorded by a counter. Since the number of bends per year of normal service, or for other intervals, may be found by observation, such tests, if due correction is made for aging or other factors, will give in a short time a measurably accurate prediction of the serviceable life of the product.

Brooms, rugs, shoes, rubber tires, and so on, may receive accelerated service tests against a revolving disk or cylinder of sandpaper, cement, or shoe leather.

Paints, inks, or dyes are tested for resistance to light by exposure to ultra-violet light many times the intensity of sun light.

Resistance to moisture is tested by a continued intermittent spraying with water, to which may be added dilute sulphurous acid, salt, or other corrosive agents to which the materials tested are to be subjected.

Permeability to moisture of paper stock is tested by one company with a solvent which is absorbed in the same manner as water would be, but several times as fast. Where it takes an hour for the tell-tale dye to penetrate the sample with water as a solvent, the new solvent will give the indication in ten minutes.

Research and Routine

Fabrics may be tested for fastness and washability by accelerated washing tests with stronger solutions. A bureau is maintained at Joliet, Ill., by the National Laundrymen's Association, for the testing of the action of washing compounds and laundry supplies on fabrics. Tests are also made, in cooperation with some of the larger textile manufacturers, on the comparative life of washable fabrics.

Many of the devices mentioned are used at present in research investigations rather than in routine testing. Research methods, however, often prove adaptable to routine testing, especially for the intermittent thorough examination of samples, to make sure that controls do not vary.

Visual inspection serves for many routine tests, such as for finish and defects. If process controls are carefully maintained and tested at intervals determined as indicated in this discussion, such visual tests are frequently sufficient.

CHAPTER SEVEN

Layout of Inspection Operations

LAYOUT of inspection operations is merely a specialized problem of factory machine layout. Ideally, the inspector should be placed at the last point in the assembly line, or between processes, or at the receipt of raw materials, or wherever the inspection naturally comes in the work sequence. The material will then flow through inspection with the minimum of handling and clerical control; good work automatically goes on to the next process; rejects, forming a small proportion usually of the total, are routed as may be required for reworking, reinspection or other disposal. Inspection processes are usually thus located in conveyorized assembly lines.

On the other hand, just as a process such as electroplating or heat treating may require equipment that cannot be conveniently placed in line with other processes, so there are, for many types of inspection, requirements for freedom from vibration, noise, or interference,

that may indicate the advisability of a centralized inspection booth or room.

Where processes are varied and intermittent, as in a job shop, and where there is in consequence no standardized order of processes, the centralized inspection department will usually be advantageous.

Definite separation of the department from the operating department, and concentration at one or a few points of all the inspection force, somewhat simplify problems of discipline as well as of maintenance of standards.

In many jobbing shops, large heavy jobs are built in one spot, and a traveling inspector becomes a virtual necessity. The traveling inspector, usually called on to pass on a diversity of jobs rather than to perform a single routine test, and often having to improvise his test circuits or testing equipment on the spot, is of necessity usually a more skilled workman than the routine process inspector. Tests usually take longer, and the method is in consequence likely to be much more costly.

Motion-Economized Inspection

Motion study may be applied with advantage to the reduction of inspection cost. In the inspection of an insulator, a number of tests were required. Two holes in the base, and two in the face, had to be at fixed distances apart. A recess in the top had to admit a closely fitting metal plug, and a somewhat similar opening in the base was also to be held to required dimensions, as was the thickness of the insulator. In addition to tests of dimension, the internal openings had to be inspected visually for adhering projections such as bits of porcelain glazed on in firing.

As these six inspections had been previously performed, the operator took up a handful of parts and passed them through one inspection at a time, using only one hand. In the revised layout, a combined testing gage was built. First the part was passed through a gage for thickness. This brought it into position for the test of alignment of the holes in the base, which were slipped over a pair of upright prongs correctly centered. Then the piece was moved forward, at right angles, over a gage that tested the clearances in the bottom opening. A continuance of the forward movement, away from the operator, brought the piece against a set of prong gages to test the second pair of holes. Finally, an upward movement brought the recess in the top of the insulator against a gage for size, and a light, correctly placed to illuminate the translucent piece from the bottom, brought any adhering particles within the recess into sharp shadow relief. The piece was not laid down from start to finish, the successive motions flowing smoothly one from the other. A substantial saving was made.

Two in Half the Time

In another case, a simple go-no-go test of a small metal bushing, the operator had picked up a handful of parts and fed them one at a time from the left hand to the right, then gaged the parts on staionary plug gages. These gages were arranged in pairs, equal and opposite, in a single fixture in front of the operator.

Using the new method, she picked up two pieces at a time (with practically no more motions than had been needed before to transfer the piece to the right hand), and simultaneously applied the two pieces to the gages. If the parts were good, they were dropped down a chute in front of the operator; if defective, through a separate pair of chutes, one for each hand, at the right and left of the gages. The time was cut about in half.

Mechanical Inspectors

In many cases, routine inspections may be made better by machine than by hand. Strip steel used in a frame assembly plant is mechanically inspected on receipt for length, breadth, and thickness. A variation of more than 0.005 inch in any of these dimensions will cause the rejection of the piece.

The strips of steel are picked up one at a time from the pile, by a set of electro-magnets mounted on a traveling bar. The next motion of the traveler places the strip in position, and a set of fingers makes contact to measure the three required dimensions. Should any one of the dimensions fall outside the tolerance, an electrical contact is made.

Following this step of measuring, two delivery arms, similar in principle to the incoming arm, are successively brought over the piece under inspection. If a piece defective from the standpoint of size is in the machine, the first arm will be actuated by the finger contacts and will pick up the piece, carry it to a pile of rejects, and drop it there. The second arm then moves over to the position just taken by the first. If the piece is not defective, it will still be there and will now be picked up and dropped in a pile of good parts.

Another interesting example of mechanical inspection is that of a small core of resistance material used in manufacturing an electrical instrument. The cores are composed of a mixture of graphite and clay, designed to produce, after baking, a certain electrical resistance. Naturally it is difficult to control this resistance within exact limits, and after baking the cores are graded into units, each of whose resistances lies within specified high and low limits.

Grading by Machinery

The grading is done by a machine that feeds the cores mechanically to a holding arm. This arm then sweeps the core over a series of contact points one point at a time. These points are connected with a series of relays arranged to trip at progressively increasing resistances. As the core contacts the appropriate relay, the latter trips and drops the core into a box of others of like resistance.

Electric lamps are also mechanically inspected for vacuum before final sealing. The lamp is formed on a revolving or indexing head. The operator supplying the first position places the stem, with filament assembled, in the machine and inserts in the upper arm of the machine the bit of glass tube that will form the bulb. Passing through

successive positions, these parts are then heated as they revolve in a ring of gas jets, and fused together. The upper tube, to which a rubber tube has been connected in advance, is then connected with an air exhaust, and in the next position with a vacuum test that rejects the bulb if the vacuum is incorrect.

The sorting of colors by the electric eye has already been mentioned. The field of mechanical inspection and testing is one with many possibilities.

CHAPTER EIGHT

The Inspection Organization

THERE is a natural relationship between designing of the product and the inspection processes which see that the intentions of the designer are realized, and which bring to light the practical, processing difficulties in such realization. Therefore it is a common, and in many cases a logical, organization plan to bring together under one department head the functions of design and product research, and those of final inspection or approval of operating standards.

Standards Department

Under this plan, subject, of course, to the policies of the general head of the business, the standards department becomes the court of last resort in passing on important cases where standards are in question and determining what the standards are.

Very commonly there is a division of inspection into two sections, under separate authority. Routine process inspection, because of its intimate mechanical connection with manufacture, and because the labor employed on this type of inspection is so often only semi-skilled, is often placed under an inspector or chief inspector who reports to the factory manager. It is, however, a good general rule that no inspector should report to an operating official who is directly responsible for the filling of orders. Thus, if the superintendent's duty is to get orders out, his judgment as to quality is apt to be strained at times, and perhaps progressively deteriorated, by the constant pressure he is under to relieve this or that rush situation. If the superintendent stands somewhat farther away and detached from the problems of immediate production, he may be a suitable superior for the factory inspection force. Generally, the factory manager is the lowest rank to whom this activity reports.

In organizations of the type under discussion, there will be, in addition to the operating or factory inspection force, a department of standards or engineering inspection which will be responsible to the general manager or the president, and through these men to the sales department and the customer, for the maintenance of the company's standards of quality. This department will investigate complaints as to quality from customers. It will compile and analyze reports of rejection by departments, processes, and individuals in order to locate and correct the focal points of trouble from which a majority of rejections usually flow.

Makes Its Own Tests

This standards department will make its own tests of quality, usually by spot checks and sampling, as well as by roving visual inspection of processes in operation. If at any point it is not satisfied with the quality being maintained, its first step will usually be to take the matter up informally with the foreman of the department concerned. It may be that the remedy of the trouble lies with the maintenance department; thus, in a large hosiery mill distinguished for its quality, an inspector's report of defects due to wear in the moving parts of a knitting machine will be the occasion for overhauling or rebuilding a particular machine in advance of the regular scheduled interval.

Or it may be that trouble is being experienced with the raw material; the inspector will again act as intermediary in getting action for the foreman. Again, incorrect design may be the cause of manufacturing difficulties, and again the matter will be reported to the engineering division by the inspection department.

When the matter of maintenance of standards is approached in this manner, and by a man tactful in winning the cooperation of those with whom he works, there are seldom serious jurisdictional difficulties as a result of the work of the inspection department.

The manufacturing or operating inspection department will stand in a dual relation to factory manager and standards department, roughly corresponding to that under which a factory cost department sometimes operates. The department will report to the factory manager for orders as to what work to inspect. The factory manager or his assistant will hire and discipline the inspectors in this division. But both the factory manager and the factory inspection department will be guided by the standards and quality policies of the standards department. In the discussion and determination of these standards and policies, the factory manager should have had a hand; he has had a chance to register any objections or make any suggestions, and is free at any time to discuss such questions with the head of the department. He is equally responsible and equally concerned, if he understands his job, to maintain the standards of quality decided upon by the responsible heads of the organization.

In other cases the entire inspection force will report to one chief inspector who will report to the factory manager, the chief engineer, or the general manager.

Putting It Up to the Foreman

The degree to which final inspection control will be carried to the top of the organization naturally depends on the importance of the function.

In many small organizations the foreman is virtually a factory manager, or in such intimate contact with all the problems of the business

and the needs of the customer, as well as the problems of production, that he is entirely qualified to maintain such standards as the concern customarily aims to deliver. In other cases, the problem of securing the required quality is not an exacting one, either because the quality is low or the processes give little difficulty. A final inspector who reports to the superintendent, like any other foreman, may be adequate.

The tendency, however, is to recognize the inherent connection between design and research problems, and the maintenance of quality standards, and to link these two and provide a clear separation of inspection from the operating organization.

While there is such a separation, however, it is important that the design and inspection departments be kept in touch with the point of view and practical problems of the operating man. Otherwise there may be a tendency on the part of the inspector to get to considering himself a court of last appeal, with final authority to settle quality questions, regardless of he operating difficulties he creates.

Committee Control

One way to maintain a practical working relationship is to place the final settlement of quality policy questions in the hands not of a single department head but of a committee, such as the committee that in many organizations acts to approve any changes in manufacturing design. On this committee, the manufacturing departments and process layout departments will be adequately represented, as well as the sales, engineering, and inspection departments. This committee will act less often as a court to settle disputes between manufacturing and inspection than as a group for the discussion of common problems, to whose solution all are expected to contribute.

Where such a committee is in successful operation, both the inspector and the superintendent will go away with a clearer perception of each other's difficulties, and a clearer understanding of the quality objectives of the organization.

To a large extent, the degree of cooperation with the operating organization will reflect the attitude the chief inspector instills into his men. Correctly regarded, their job is quite as much that of diagnostician of troubles and helper in their removal, as it is of being "rejectors," as one inspector put it[1] and as many shop men regard the inspector. The chief inspector or his assistants should frequently, if not regularly, participate with the foremen in such activities as weekly production or safety meetings, or in the round tables that many plants hold for the education of foremen and the discussion of common problems. Thus the inspector will not only gain a better understanding of the difficulties of the production man, but may participate in discussing

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It is obvious that the quality of a product and the cost of producing it must bear the correct relationship to its sale; that the spread between cost and selling price controls volume of sales — and hence net profit

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remedies, perhaps using his research facilities to find a solution or adding his recommendations to those of the operating heads, in the request for appropriations for new machinery repairs, better light, or other requisites to improvement. He will thus find himself aligned with the foreman on so many questions that there is little chance for a feeling of antagonism to arise.

Other steps may be desirable to make foremen and operating men "quality conscious." Several organizations use the plan of having an annual or occasional "open house" day, at which the families and friends of workmen, as well as townspeople, newspaper men, and customers are welcomed and shown through the plant. On such occasions the men themselves, many of whom ordinarily see or comprehend little that goes on outside their department, get a better idea of what it is all about and a greater respect and pride for their firm.

Learning More about the Product

In other cases, visits are exchanged by groups of foremen from different factories that have processes in common. At least one firm has tried the plan of sending some of their foremen or operating men out with salesmen to call on the firm's customers, to the end that the product shall be associated in their minds with the services it is to perform and the people who use it.

An interesting project designed to direct the attention of an organization to quality was undertaken by a printing concern. The company felt that it should be possible with modern equipment to produce work of as great beauty and artistic quality as had been made by hand, with much cruder equipment, by the craftsmen of an earlier day. The publication of four books, illustrated by contemporary artists and each the best in design and execution of which the organization was capable, was undertaken. Throughout the processes of production, the books were made a challenge to the force to show the very best they were capable of.

The story is told of a prospective customer who asked a friend of his what he thought of the car his company manufactured.

"That bunch of junk? I wouldn't have one if you gave it to me," was the reply. Something was radically wrong with that factory, either in the standards of quality they maintained, or in the way they hired, trained, and maintained the confidence of, their men.

Quality is thus not merely a matter of design, or of gages and measuring devices. These things are the tools with which the organization works. But the vital element is one of morale, of the inherent conscientiousness of the company and of the effectiveness with which its representatives train their men to produce good workmanship and insist on its continued production.

[1] *Quality Control*, by G. S. Radford, Ronald Press, 1920.

CHAPTER NINE

Managing the Department

WHERE the inspection department force is large enough to call for more than a few men, the organization may fall into two general divisions. The first of these (where not already assigned to the operating departments) will be the organization for routine inspection, with inspectors and inspector foremen or foreladies. This will primarily be a routine organization, concerned with sorting the work and applying the gaging and other inspection operations.

For this type of work, what is wanted is someone who will carry out orders faithfully. Skill as an operator or workman is not usually necessary and may indeed be a handicap, the habitual ideas and standards of the workman differing, perhaps, from those he is expected to enforce.

Certain other qualifications are often desirable. Among these are ability for sustained attention to routine operations, and quickness of reaction time—the time taken by an individual between the perception of a condition, as seeing a good part, and the individual's response, which is to drop the good part in the box. Good eyesight and delicacy of touch also are usually desirable. Women frequently make better inspectors than men, from these standpoints.

The Research Group

The second division of the department will be the research and investigating group. This division will at frequent intervals re-inspect the work done by the routine inspection, as well as take samples from time to time at all process points. Investigations dealing with the correction of quality problems will be made by this division, in cooperation with, or at the request of, the foreman concerned.

New tests, gages, and methods will be designed by this department. Here also will the reports of rejections be analyzed and summarized for the executives concerned, from the detailed weekly or daily report to foremen of spoilages and their points of origin, to the general monthly summaries that go to the factory manager.

An Analytical Viewpoint

Testing of gages and other instruments will be done in the laboratory —small and simple or large and complete, according to needs—with which this department will be equipped, or which should be at its service if a separate research department is maintained.

The type of individual best adapted to this work will differ substantially from that desirable for routine inspection, although this does not preclude the development of the necessary qualifications by a certain percentage of routine inspectors. Much more the research and trained analytical point of view are desirable; this type of inspector is a diagnostician. Some experience in the processes is also desirable; the inspector will be better able to deal with a defect if he understands why it was produced.

Although a certain measure of tact, or at least the ability to avoid antagonisms, is needed by the routine inspector, the actual contact between inspector and workman will usually be made through superiors in the inspection department to whom the trouble is reported, or to a foreman who is himself experienced and in a position of responsibility. With the research and standards division of the department, however, tact, persuasive powers, and ability to understand the other fellow's point of view are especially important.

Managing an inspection force presents problems of personnel corresponding to those met with any force of men. Some hints have already been given as to the type of person suited to each of the two general classes of inspection personnel, the routine inspector and the type of man used for traveling and non-routine inspections, for investigation, research, and analysis of quality troubles in improvements.

Routine inspectors will be recruited from among the same type of employee as other routine workers, with emphasis on, and perhaps selective tests for, the special qualities mentioned. The research and analytical type may be drawn either from engineering graduates with some shop experience, or from foremen, assistant foremen, or workmen. Usually a man of an ingenious turn of mind, with some flair for things mechanical and an aptitude in devising answers for mechanical problems, makes a good inspector if he is also able to get along with people.

What Wage Plan?

The question of pay for inspectors is one often discussed. From time to time, bonus and piece-rate plans are proposed. Under these plans, a standard of daily or hourly output is set by time study and observation. The operator is then paid in accordance with one of the usual piece-rate or bonus plans, for output. The work of each inspector is re-inspected on a sampling basis; if found to contain parts that should have been rejected, the original inspector may be called on to do the work over, or more commonly the work will be re-inspected by another inspector and the first one penalized according to a scale that makes careless work costly.

Cases are occasionally met in which inspectors are paid for errors discovered or rejections made. This would not be a workable plan unless the normal percentage of defective work was known and remained fairly constant.

Commonest plan of payment is on a straight time basis, usually hourly although sometimes monthly. Where supervision is good, especially where there are established standards of performance as to quantity and accuracy of work, this plan of payment will probably be best suited to the majority of inspection situations.

However, on routine inspection work where speed is desired with accuracy, a good plan is one that combines an adequate guaranteed hourly rate, systematic sampling, re-

inspection, good supervision, and a small but appreciable bonus for output, the latter being enough to direct the operator's attention to production without forming so large a part of the total pay as to constitute a temptation to slighting the work.

Training of inspectors is a subject to which considerable attention has been given. The Western Electric Company[1] has conducted a school for prospective inspectors and assistant inspectors, modeled along the lines of a foreman's discussion section. A program was laid out covering the following subjects:

Cooperation as a Supervisory Responsibility.

How to Give Orders.

Job Teaching.

Introducing the Man to the Job.

The Setting of Individual Production Standards.

Analyzing and Planning the Job.

Rating of Quality.

Other subjects were also discussed. The course was followed by a short examination, and those who qualified were put in a reserve, from which promotions were made to the rank of inspector as the need arose.

It was found that proficiency in the course did not automatically indicate success as an inspector, but even for the men who did not pass the course there were useful by-products in the way of better workmanship. Inspection, in turn, was used as one of the sources from which qualified foremen could be drawn.

How Much Training?

To the company without an inspection organization or with perhaps one lone inspector or two, such elaborate measures for organization and training may seem to border on the fantastic. It is a fact, however, that in busy times when labor turnover was high and reliance had to be placed on new and unskilled workers to a considerable degree, the force of inspectors has sometimes run as high as 10 to 20 per cent of the direct productive labor.

In a large shop this might mean up to 2,000 inspectors. Modern scientific methods of sampling, and attention to the preventive and corrective phases of inspection have tended to lower these ratios, at the same time improving and assuring more uniformity in the product. The general use of more refined productive processes and better controls has exerted a similar influence on the size of the inspection force. The intimate relationship between securing good workmanship, provision of good equipment, and inspection expense is apparent.

Apparent also is the necessity of unity and continuity of policy as regards quality on the part of the management. The inspector does not produce quality, except as he secures the cooperation of the shop in carrying out corrective measures. Granted suitable equipment, quality is a matter of training, discipline, and morale. It need cost little more to secure good quality—indeed, it may cost less—than to tolerate careless workmanship and high rejections.

First Costs May Be High

It has been the experience of one company which has done a great deal of systematic and intelligent work in improving quality that, at the beginning of a drive for raising quality standards, the costs of inspection are high. As the workmen learn what is expected of them and receive instruction in securing quality, and as maintenance is stepped up to enable the equipment to do its part, the costs of inspection drop to something like the old level. Adequate control required at first a good deal of 100 per cent inspection and high percentages where samples were taken. As performance became more dependable it was possible to reduce the percentage of inspection.

Points of antagonism between shop and inspector have already been referred to. To the workmen, rejection is a direct and pointed criticism, and usually money out of pocket. To the foreman and production superintendent, rejection may mean not only these discomforts but at times a most irritating interference with deliveries whose importance has been stressed until it seems as though everything else should give right of way to the necessity of keeping the sales department's solemn promise, or helping the customer out of a bad jam.

Less Spoilage

It is a mistake to foster this antagonism. Inspectors who will pass defective work simply out of a desire to be a good fellow, or to curry favor with a foreman, have no place, of course, in the department. But the inspector or his superior who takes a rejection up with the operating men, while he has a duty to perform which it is to the interests of all to have well done, should be as concerned as is the production man to meet the emergency as well as possible, short of a failure in the company's obligation to the customer. And frequently the emergency in deliveries may be avoided by better scheduling, by carrying correct reserve stocks, by breaking the process into sub-assemblies of which small stocks, or temporary stocks, are carried, or in processes where spoilage of a certain per cent is normal, by starting the order with safe overages. Again, the closer the degree of process control, the more uniform the materials, the more skilled the men, and the better the equipment, the fewer will be the spoilages.

CHAPTER TEN

Applications of Inspection

INSPECTION is a general process. The cycle of research and fact-finding, planning or decision, dispatch and performance, and inspection or follow-up is performed in some manner, with emphasis now on this phase, now on that, wherever work is performed. Among the commoner industrial situations for which inspection is definitely organized, in addition to the inspection of factory operations thus far dis-

[1] "Quality" by Carl W. Gates, *Bulletin of the Taylor Society*, April, 1931.

cussed, are inspection of goods received from vendors, inspection of office work and correspondence, and inspection of tools, plant, and equipment (usually handled by the maintenance or plant department).

In all these cases, the general procedure will borrow much from the methods just described. Economy of inspection costs may be obtained here as in other cases, by the selection of strategic points, and by the application of sampling principles. The analysis and correction of conditions revealed by inspection is equally important and may be done in much the same way. A few special points may be noted in vendors' inspection and the inspection of office work.

Inspecting Purchased Materials

The first necessity in the inspection of purchased materials is systematic procedure. Such things as promptness in reporting the acceptance of goods so that invoices can be paid in time to take discounts, or of orderly identification so that lots from one vendor will not be mixed with other shipments from the same vendor or other vendors, would seem to be so elementary as to call for no comment. Yet there are plants in which, during a busy period, relations with vendors were reduced to a hopeless tangle, thousands of dollars in discounts were lost and short-count, defective, and stuffed orders were accepted simply because the receiving department had failed to handle the receipts systematically.

It is not the purpose of this article to deal with receiving department procedure save to emphasize the importance of having a systematic and prompt routine. From the standpoint of acceptance of purchased materials, it is a first rule that all receipts from vendors should be segregated and remain the vendor's property until properly passed on by the inspector. For this purpose the temporary storage space in the receiving room is usually divided into two compartments, physically separated by a solid or wire partition, the first containing materials not accepted, the second, materials accepted and ready for delivery to production or stores.

For carload lots, this separation may mean essentially prompt inspection routine if demurrage charges are to be avoided. Where such shipments are received continually from the same source, it may be advisable to maintain an outside inspector in the vendor's plant to insure the shipment of acceptable material.

The rule of refusing to take title until the goods have been accepted also means a systematic handling of rejected or doubtful material—first, so that it may not inadvertently be mixed with the company's property

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Quality control is the tool of management that sets up and maintains a balanced relationship between the five fundamentals—quality, cost, selling price, volume of sales, net profit

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and used up; second, so that it may not be damaged or liabilities respecting its condition created with the vendor.

It is obviously important that the inspector be supplied with full specifications as to the agreed qualities of the goods, and be familiar with trade customs respecting the same. Affiliation and activity with such associations as the American Society for Testing Materials should be encouraged.

Danger of Corruption

Vendors' inspection is one of the points at which corruption of company agents is most possible. Some time ago the newspapers reported the case of a company that had been buying carloads of paper stock, as it supposed. Suspicions were accidentally aroused. An investigation was made. It revealed the fact that the inspector was in the pay of the vendor and had been certifying the receipt, as full carloads, of practically empty cars, each containing perhaps a bale or two of stock. Such cases, unfortunately, are not uncommon and are potentially a danger in any vendors' inspection.

One often used answer is the rotation of inspectors, especially traveling inspectors. But this plan, while affording some measure of protection, does not prevent the possibility that an inspector who has learned that it is possible to defraud the company, will establish similar relations in his next assignment. And it does involve the continuing difficulty and irritation of getting new men to understand the job and deal in an acceptable manner with the company's vendors.

Best protection against fraud or influence in the acceptance of vendors' materials is a systematic stores and factory procedure. With such a procedure, which need involve little or no increase in cost, simply better methods, it should be possible at any time prior to shipment to locate positively all the foremen, storekeepers, inspectors, and others who had any major responsibility in handling the goods. With such a system, were defective material being accepted, the fact would be quickly brought to light and the responsibility traced. The knowledge that such a control exists acts as a powerful deterrent to temptation.

The Right Man for the Job

Irregularities in count or quantity would be shown up in similar fashion by a good system of stock records. And finally, the kind of attention to training and workmanship, the cultivation of a professional attitude toward the work which has been mentioned as a byproduct of training courses or methods and of good supervision, furnishes one of the best assurances that there will be no room for temptation.

Careful initial selection should also be made for such responsible jobs, from men who have been with the company long enough so that their characteristics are known. References should be investigated, but should not take the place of a tryout in other jobs before being made an inspector of vendors' goods.

With all these precautions, sporadic fraud is still a possibility, and a single transaction may involve a

good deal of money. Such possibilities should not be forgotten. But the coming to light, as still happens, of cases involving material or money peculations extending over a long period of years is in most cases an evidence of failure to understand modern principles of record keeping and control through over-all, interlocking checks.

Sampling Office Work

Inspection of office work bears many similarities in principle to shop inspection. Sampling will be largely relied upon. Thus it is good practice occasionally to read the carbons of correspondence, to check the quality of stenographic work for one thing, and, more important, to ascertain and, if necessary, correct the attitude and tone used by the correspondent in his business letters. Similarly, the way in which receptionists, telephone operators, and others who meet the public conduct their contacts should be observed without the operator's knowledge from time to time.

A question that may arise in such sampling is how to avoid giving the operator the feeling that she is being unjustifiably spied upon. The following suggestions may be of help in answering this question:

1. The operator should be informed in advance that his or her work is subject to such inspection.
2. The discovery of faults should be made the occasion for correction, for teaching rather than reprimand so long as the operator indicates a desire to improve.
3. In general, the inspection should not be made by one who is disguised as a fellow-workman, but by one who, although possibly a stranger to the operator, is officially designated and recognized as an inspector.

Importance of Identification

In addition to sampling methods in the office, an important method of control is through the identification of all important operations. Thus, the time card may contain space for notation of the initials of the foreman who approves the work, the inspector, the clerk who posts it to the progress records, and the clerk who posts the payroll. Should an error occur in any of these operations, it can be traced back at any subsequent time.

Right Way to Inspect and Teach

Well do I remember the methods used by Carl Barth, distinguished industrial engineer, in inspecting office work. It was his custom, on his periodical visits to the office, now and then to pick out a shop order at random except that his eye usually lit on the most dog-eared and bedeviled document in the office. Then he would begin methodically at the beginning, and trace through every step in the operations. How long had it taken to get the job through the electrician's department? If the answer was vague or evasive, back to the records for the answer. Why had the delay occurred? What steps had the follow-up man taken to remedy the situation? What difficulties had he encountered?

Here was an order that showed short delivery. What was the reason for that? And so through one or two or three orders, as the need seemed to be and as time permitted, teaching, correcting, praising, or censuring as the case demanded, and getting a first-hand idea of the weak points in the shop and office as he went. A good example of the right way to inspect and teach.

Disposing of Rejects

Such follow-back would have been impossible without the systematic identification by signature to which reference has just been made. Carried through the whole system (and it takes but a moment to initial a form which must be handled anyway), responsibility can be clearly fixed at any time. Much of the time the identification is not used; it is valuable when it is necessary to locate and correct the occasional offender.

There remains for discussion the disposal of rejected work. The first step may be verification of the rejection; often a routine inspector passes in a preliminary way on all the work, and a second inspector makes a more careful and final decision on the parts tentatively rejected. The next step will be diagnosis and correction. This may involve merely a record of totals for statistical analysis, or an immediate conference with those responsible.

The next step is disposal. Under some piece-rate agreements, the workman is expected to make good his own defects, and is sometimes held responsible for all work he accepts from the previous operation. This method would be impracticable in progressive lines, and frequently constitutes an undesirable interruption to production in other cases. Unless necessary for disciplinary reasons, it may be better practice to pay the operator only for good pieces produced, and not to burden him with the irregular work of making repairs. This work will be handled by a separate department, specially equipped and organized to handle jobbing, experimental, repair, and other irregular and non-standard production jobs.

Repair or Scrap?

Before repairs are in order, however, a disposition should have been made by the inspector, or by the inspector and foreman in conference. It may be advisable to scrap the piece. If slightly oversize or undersize, it may be possible to use it, where interchangeability is not of importance to the customer, by assembling with other work with a corresponding irregularity. Interchangeability, so often referred to as one advantage of standardization, frequently is far more important to the manufacturer from the production standpoint than it is to the customer.

For Sale as a Second

Again, the inspector may classify the piece as a second, to be sold, either with or without further processing, at a reduced price and/or to a cheaper market. Or the piece may be sent for repair.

The disposal of scrapped materials is sometimes assigned to the inspection department, but is more properly a function of stores. Once a material has been classified as scrap, it becomes a new kind of material. Scrap may arise from various situations, such as condemnation of obsolete material, over which inspection has no jurisdiction.

INDUSTRY'S POWER

Its Economical Procurement and Use

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Chapter One

FOR LOWEST POWER COST

Take Advantage of Improvements in Method and Equipment

PRACTICE in the power plants that industry is installing today is not what it used to be—which is a good thing from the standpoint of lower power costs. Along with improvements in practically every item of steam generating equipment and auxiliaries have come many betterments in operation. Taken together they have raised the over-all efficiency of steam generation by a surprisingly large percentage.

Consider a single item—boiler efficiency. A few years back it hovered around 60 per cent. Many plants do little better even now. Yet today an efficiency of 80 per cent can easily be obtained.

It is not possible to consider in detail the improvements made in every item of steam generating equipment, or to evaluate them in percentages, if only for the reason that operating methods and practices have likewise been improved. Nevertheless better equipment, I feel, has played the larger part. Let me cite a few of the more important advances of recent years.

AUTHOR

▶ **PHILIP W. SWAIN** ◀

Editor, Power

Naturally, fuel-burning equipment has been given much attention. Today's stokers are more reliable, longer lived. They cost much less to maintain, are able to handle cheaper grades of coal. This last is particularly important, because it may easily save 50 to 75 cents a ton in the cost of coal. With these betterments have come far greater capacity to handle peaks, and increased flexibility of control.

For plants that prefer pulverized fuel, new equipment is available in which the use of hard and wear-resistant alloys gives longer life and cuts maintenance cost. Oil burners, too, have been improved to give better atomization, hence more perfect combustion, to permit closer regulation of air supply, make possible the use of lower grades of oil, and avoid the steam waste of early forms of steam-injection burners.

Equipment has been developed for automatically weighing or measuring fuel and water with a high degree of accuracy. When used with flow meters that record steam consumption, it enables the operators to keep a close check on efficiency.

Measuring the amount of carbon dioxide (CO_2) in the stack gases is

"Double, double toil and trouble; Fire burn, and cauldron bubble"—true now as when the Bard of Avon said it, except that modern equipment takes out most of the toil and much of the trouble

one of the simplest and most valuable means of checking the efficiency of combustion. The equipment used for this purpose has undergone many refinements to make it simpler and more accurate.

Instruments Important

Instruments recording pressure, temperature, and draft have likewise progressed. Modern types are accurate and reliable, may be grouped together at any desired point. A boiler plant without these tell-tales of operating waste it like a store without a cash register.

Available water supplies generally need treatment to fit them for boiler use. Otherwise scale coatings waste fuel and destroy tubes; boilers disintegrate from corrosion and foam dangerously. Apparatus and methods of treating boiler water have been brought to a high degree of perfection.

The oxygen of air dissolved in boiler feed water is often the cause of serious corrosion. De-aerating heaters are available to remove the air before the water reaches the boiler. In most cases they completely prevent corrosion.

Water-Cooled Furnace Walls

One of the interesting and important developments in industrial boiler installations is the water-cooled furnace wall. Boiler tubes filled with water protect the firebrick walls from the intense heat.

Power plants got along for many years with plain firebrick walls because boilers were badly operated. The old-time operator flooded the furnace with too much air for the fuel burned. This was fine for the walls, but hard on the coal bill, because every extra ton of air fired meant another ton of hot gases passed up the stack.

Combustion experts have long urged that excess air be cut down, and this has gradually been done by progressive operators. But, as efficiency goes up with air economy, so does furnace temperature. As a result, overheated firebrick walls begin to fail rapidly.

Water-cooled furnace walls have been used for some time in central station plants. Now they have come into the industrial plant, making possible the efficiency of a hot furnace with the maintenance requirements of a cool one.

It was soon discovered that each foot of wall tube produced as much steam as several feet of tube in the boiler proper. So these boilers with water-cooled furnaces work harder, although with less wear and tear.

Air preheaters have made possible a further reduction in boiler surface. In the plate type of preheater, hot gases leaving the boiler furnace pass through certain spaces in a stack of steel sheets, while air for combustion goes through other spaces, and is heated before entering the furnace.

These new boilers, with their inbuilt features, their fans and heat-recovery units, cost more per unit of physical size, but will evaporate two or three times as much water every hour. One new boiler can therefore replace three old ones.

Boiler valves and attachments now have seats and fittings of resistant alloys, reducing wasteful leakage and maintenance cost.

A variety of new, convenient, and ultra-safe water-level gages and high- and low-water alarms have been made available.

All auxiliaries, such as small turbines, pumps, and fans, are of much better design and far more efficient. New feed-water pumps alone will often save their cost in a single year.

Superheaters hold more constant steam temperature, making it safe to enjoy the economy of higher temperatures.

Steam-driven prime movers, turbines in particular, have been brought to new levels of efficiency, while improvements in design and the use of alloys have lengthened the life of blades and reduced maintenance requirements.

Diesels Become Prominent

Although the diesel engine is 40 years old, and therefore not a new development, it has come into great prominence during the past few years. Today's interest in this remarkable prime mover is largely the result of a better knowledge of its proper applications and possibilities. From early days the diesel has been exceptionally efficient. It has for years been able to deliver a horsepower for about 0.4 pound of fuel oil an hour. Developments of recent years have, however, greatly improved its reliability and life. Moreover, higher operating speeds and quantity production methods are bringing down the first cost.

The trend toward the use of high pressures is among the most significant changes in steam-plant practice. Whereas 150 pounds was about the limit for the average plant a comparatively few years ago, with the pressure in most plants well below that figure, the tendency in new installations that must simultaneously generate power and large amounts of process steam is to use pressures between 400 and 700 pounds. Some exceptionally large installations have been designed for 1,400-lb. pressure.

What Pressure Steam?

It requires no more fuel to produce a given quantity of steam at 500-lb. pressure than it does to produce the same quantity at 150, but the higher pressure steam will produce much more power, particularly when some is "bled" off after being partly expanded through an engine or turbine.

Selection of the most economical steam pressure must be based on a thorough study of the conditions surrounding each installation, rather than on general trends. It is a job for a trained power engineer.

Bleeder turbines, in which a certain amount of steam is drawn off before it has passed through all the stages, are being widely used. Savings from higher pressures and bleeder turbines may run as high as 40 per cent of the total coal bill.

High steam temperatures produced by passing the steam through a superheater are also in vogue. Hotter steam works more efficiently in turbines and engines so that less of it is required. Hence, less coal.

Tube-type heaters save additional money by preheating the boiler feed water well above the 212 degrees Fahrenheit that used to be considered the practical limit. Every 10-deg. rise in the temperature of the feed water clips 1 per cent off the coal bill.

To meet popular objections to smoke, dust-removing equipment is now coming into wide use, and furnaces are designed to burn any fuel, including soft coal, with little smoke.

By raising boiler efficiency from 60 to 80 per cent, burning cheaper coal, handling coal and ash mechanically, and reducing maintenance, the cost of producing 1,000 pounds of steam may often be reduced 30 or 40 per cent. Add to this a very substantial reduction in steam consumption, through the use of higher pressures, bleeder turbines, and so on, and it is frequently possible to cut boiler-room costs in half.

FOR LOWEST POWER COST

Select and Burn Fuels to Fit Specific Conditions

COMMON limits of the principal components of steam costs expressed in cents per million B.t.u. net steam output are:

1. Fuel	12	35
2. Water and minor supplies	0.75	2.5
3. Operating labor and supervision	3	7
4. Maintenance	2	5
5. Fixed charges	3	7
6. General and miscellaneous	0	2
Total	20.75	58.5

Fuel is obviously the most important item. Second in importance may be items 3, 4, or 5, although, if maintenance comes second, something ought to be done about it.

When considering how to obtain minimum steam cost, it must be borne in mind that fuel cost depends not only on the price that has to be paid for fuel, but also on how efficiently it is used.

The price that has to be paid is not merely a matter of bargaining. Fuel-burning equipment, furnace design, and sometimes operating personnel impose limitations in the choice of fuel. A low-priced fuel may be the cause of higher furnace costs; or it may be impossible to get the needed capacity, or to burn a low-priced fuel as efficiently as one of higher price.

These points are, however, often over-emphasized by boiler-room operators and salesmen of high-priced fuels. Quite frequently it is possible to burn a lower grade fuel successfully with some additional attention and effort from the operators. The only way to find out is to try different fuels.

Lowest Price per B.t.u.

Start with the fuel that gives the lowest price on a heat-content basis—provided, of course, that it comes within the range of what the fuel-burning equipment can handle. If equipment and refractories appear to stand up all right and the efficiency is anywhere near the practical maximum set by the design of the installation, the tests may end right here. A simple calculation will tell what price it would be worth to obtain the maximum efficiency, and oftentimes the next higher priced fuel is above this range.

If, however, other fuels are available within the calculated price range, continue with the tests. Each fuel should be given a test run of at least a week, more if the evidence is not conclusive after the first week.

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Three Steps to Efficiency

How efficiently the fuel is used, depends first on the design of the installation; second, on operating conditions; third, on the operating personnel. The design of the installation determines the maximum efficiency that can be obtained. It may be anywhere from 60 to upwards of 90 per cent. To determine the maximum, it is best to run a test of at least 8 hours' duration under the most favorable conditions and with expert operators, also with a man in charge who doesn't make figures lie.

Operating conditions are never equal to the most favorable conditions. Fluctuating load and banking periods will make the maximum efficiency obtainable over a period of, say, a month anywhere from 1 to 5 per cent lower than the maximum test efficiency. These are, then, the best average results that can be expected.

If actual results are much lower, they may be due to unsatisfactory operating personnel, bad working conditions, or lack of necessary instruments and control devices. Weeding out unsatisfactory operators is not always an easy matter, but it is worth fighting for. Without the proper men, even the best power plant is a bad investment, and instruments and control devices are of no use. Instrument readings have to be understood and interpreted correctly. Automatic controls are automatic only as long as they are taken care of properly.

If the maximum obtainable efficiency as determined by test and operating conditions is low, it may pay to make some plant improvements.

What should be done, is a matter for a man of experience and good judgment to decide. If the man in charge is capable, he is best suited to make recommendations for his own plant. If not, a consulting engineer should be called in. When the proposal involves a large expenditure it is well to have local recommendations checked by an outside consultant.

Cost of water should properly include the cost of treatment or softening; hence it is not always the cheapest water that is the most economical. Improperly treated water carries with it high maintenance and boiler-cleaning costs. If the plant does not have a man well posted on water treatment, it pays to get advice from some good concern that specializes in this kind of service.

It may be superfluous, but sad experience prompts the warning: Watch out for quacks and patent medicines.

Don't Pay Labor Less

It never pays to obtain low labor and supervision costs by paying lower wages than those prevailing in the locality of the plant. Savings thus obtained are likely to be more than wiped out by inefficient and careless operation. The value of equipment and of material handled, compared to operating labor cost, is higher in a power plant than it is in most other places. Waste of a few per cent of the fuel represents a considerable sum. On the other hand, if labor costs can be cut down by the use of better equipment, do so—provided, of course, that the saving in labor amounts to more than interest, fixed charges, and maintenance of the new equipment.

Cost of maintenance should be a

comparatively small item in the cost of steam. The natural tendency is for it to increase with the age of the plant. It is usually futile to try to formulate general rules, but with regard to maintenance one rule can be laid down: It pays to make repairs before conditions become urgent.

Tube failures are more difficult, if not impossible, to predict. If they are frequent and extensive, the cause is usually faulty feed-water treatment, or in some cases, particularly with fuel oil, faulty furnace arrangement.

High refractory maintenance is often traceable to the characteristics of fly ash, and it may pay to change coal. In other instances it may be due to high combustion rates, insufficient combustion air, or the wrong kind of refractories. Overfire air injection, air-cooled refractories, or water-cooled furnace walls are remedies that should be investigated.

Fixed charges, which comprise depreciation, interest, taxes, and property insurance, constitute an appreciable item in the cost of steam, particularly in new, highly efficient plants. It is plain enough that fixed charges are higher for a new plant than an old one that has had part of the investment written off. It may not be so generally realized that high efficiency is paid for in increased fixed charges. If it were, there would be fewer plants designed for extremely high efficiencies. Fixed charges have one bad feature; they are *fixed*. Operating skill and effort cannot change them. No plant improvement can lower them.

Power experts estimate that industry wastes from 20 to 50 per cent of the power it makes and a considerable amount of the energy it buys. In the interest of low-cost production—to bring about wide distribution of industry's products — these wastes should be converted into savings—that is, into net profits

When planning small- and medium-sized industrial power plants it is well to be wary of extremely high efficiencies. A highly efficient plant is usually more complicated and presents more delicate operating conditions. Such conditions demand close supervision by well-trained experts, which a small plant cannot afford. The keynote should be simplicity and reliability.

The degree of efficiency to aim at, depends on the price of fuel, the size of the plant, and labor conditions. High fuel price justifies a larger investment in equipment for increasing the efficiency. With a large plant the investment will be less per unit of steam output, which will permit heavier investment in heat-saving equipment. The cost of operating labor and supervision is also less per unit of steam output in a large plant, and this fact will permit more to be spent on testing and supervision of additional or more complicated heat-saving equipment.

Power Costs and Steam Costs

Finally, if good labor is to be had and can be expected to be available permanently, a complicated plant can be turned over to the operators with more assurance against breakdowns.

When considering steam costs in an industrial plant it is often necessary to consider power costs at the same time. Whenever exhaust steam from prime movers is used to process work it is a matter of accounting as of how much of it is steam cost and how much is power cost.

So far as the plant manager is concerned, it is advisable to consider the total cost of the two items whenever alterations or new installations come up for a decision. Instead of asking: "Is generated cheaper than purchased power?" it is better to ask: "Is steam plus generated power cheaper than steam plus purchased power?"

Whether power is considered as a byproduct of process steam, or the latter as a byproduct of power, the fact remains that even when all exhaust steam is used for process work and no power is generated with condensing prime movers, some additional fuel has to be burned and some additional investment is required in the boiler room. The fixed charges on this additional boiler-room investment have to be taken into account when considering generating power. If the cost of generated power is not considerably less than that of purchased power, it is my recommendation to stay away from generation.

As a general rule no industrial plant has any justification for generating power with condensing prime movers. The exceptions would be: (1) An existing plant that is wasting low-pressure steam; (2) a plant with fluctuating loads where a condensing unit may be justified to guard againt waste of exhaust steam.

In contrast to this, it is tempting to put down as a rule that no industrial plant that uses large quantities of process steam is justified in purchasing power. But that rule will not hold for small plants; the item of operating labor entering into the cost of power often becomes prohibitive.

Pressure and Temperature

When considering power generation, the choice of steam pressure, likewise temperature, is important. With higher steam pressure more power can be generated from a fixed quantity of steam, but with higher steam pressure there go more expensive boiler equipment and the need for more expert supervision. The proper procedure is to fix the pressure high enough to get the needed power out of the process steam used, and no higher.

Ample leeway should be allowed to guard against exhaust steam waste. Consider carefully the highest power load that may coincide with a period of low steam consumption.

I should put the advisable limit of steam pressure at about 400 pounds for small plants, and about 600 for larger plants. This viewpoint is wide open to argument, but I feel that an industrial plant has to put more stress on simplicity and ease of operation than does a central power plant.

With regard to steam temperature, the governing factor is to avoid excessive moisture in the exhaust steam; with high back pressures it may be advisable to have some superheat in the exhaust. As a limit I should suggest about 500 degrees Fahrenheit for steam going to reciprocating engines and 750 for steam to turbines. This recommendation again is open to argument, but the average industrial plant should be conservative.

FOR LOWEST POWER COST

Utilize Steam with Least Waste

STEAM is a necessity in practically every industrial establishment. In some plants it may be required only for building heating and hot water supply, but in most instances it is also needed in varying amounts for processing operations. Since it is commonly generated on the premises, a considerable investment is necessary for building space, equipment, and distributing facilities. Often the fixed charges on this investment, together with fuel, labor, and other charges that make up the cost of producing steam, become a sizable item in the cost of the manufactured product. It is therefore important that some thought be given to using steam efficiently.

Maintaining Heat Balance

When exhaust steam from turbines, engines, pumps, and other equipment is available for process work and building heating, it is not always utilized to the best advantage. Exhaust steam will be used most efficiently when a good heat balance is maintained—that is, when there is little or no wastage of exhaust to the atmosphere at any time.

Frequently it is difficult to maintain such a heat balance, because process steam demands do not always follow power demands. Again, when the exhaust steam is used for building heating, it means a seasonal load that disturbs the heat balance during the off-heating period. Plants that use large quantities of hot water usually have the opportunity to maintain a good heat balance by installing large hot water storage capacity.

Often the heat balance obtained with turbines or engines is so poor, and offers so little opportunity for improvement, that continuance of their operation, as compared with a more efficient arrangement, becomes a question of economic justification.

Aside from these considerations, inefficiency in steam usage may result from unsuitable steam characteristics, inadequate or poorly installed piping systems, excessive radiation losses, wastage caused by leaks and defective steam traps, and various other conditions.

Usually wastage and radiation losses are the most important, since they are not always apparent, or because their significance is not considered seriously.

Steam pressures at the point of usage are determined by the requirements of the process equipment.

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Frequently several different pressures may be needed, with still another pressure for building heating. When the plant was designed, these conditions undoubtedly determined the selection of pressures for distributing steam to the various usages at highest efficiency, as well as the layout of the distributing system.

Continued growth in manufacturing facilities, however, often results in expansion of the steam distribution system until it becomes so intricate and so poorly adapted to the requirements that losses are excessive. Frequently there is an excessive amount of piping, much of it in duplicate. There may be excessive pressure drops that affect process equipment adversely and result in excessive steam consumption.

Where such conditions exist, revamping of the system, possibly some readjustment of steam pressures, is indicated to improve factory production and steam economy.

High-Temperature Steam

Superheated steam is undesirable for most process work and building heating. It retards heat transfer in most types of heat exchange equipment and necessitates greater heat transfer surface than saturated steam at the same pressure. Necessary use of special metals for fittings, valves, and accessories adds materially to their cost.

If high-temperature steam is required for some process, it is best to supply it from a separate source and distributing system. The source may be a high-pressure boiler delivering saturated steam, or, if saturated steam can be used advantageously, it may be more economical to use a moderate-pressure boiler with a superheater.

Where the entire factory is supplied with superheated steam, it is invariably advisable to install desuperheaters to provide saturated steam for process and heating.

Considerable loss is often caused by lack of insulation, inefficient materials, poor application or deterioration of insulation on piping and equipment.

Certain standard thicknesses of various types of heat insulation for different classes of service have been set up; if these standards are followed, satisfactory results will usually be obtained provided the materials used have the proper characteristics.

What Heat Insulation

A sewed-on-canvas covering over the insulation involves a higher first cost, but has the advantage of maintaining permanence of efficiency and appearance, and lends itself readily to painting.

Insulation of flanges of piping, valves, and fittings is a doubtful economy except for very high temperature steam lines. Flange covering should be easily removable for access to bolted joints, and in that form it is somewhat expensive. When removed, it is frequently damaged and never replaced.

Outdoor overhead and underground lines carrying steam and hot water are a source of considerable loss when not properly insulated. Such lines require a greater thickness of insulation than indoor lines, and the insulation must be protected against deterioration from weather and moisture. Insulating materials have little value as such when they become wet.

Process equipment using steam is usually purchased on specifications and guarantees for productive capacity, but often steam consumption is not given the same consideration. Specifications for minimum steam consumption per production unit will assure the best possible steam efficiency, and the manufacturer will see that proper heat insulation is provided.

Steam wastage due to inefficient or defective steam traps can be large, is not usually apparent, is often difficult to detect. Periodic inspection of traps is advisable. To facilitate inspection and repairs without interrupting service, three-valve bypasses are desirable on all traps, except the smaller thermostatic types used on heating systems.

Traps More Effective

In recent years trap manufacturers have greatly improved their product, and the inverted-bucket types have come into considerable favor because of their simplicity.

Often there is a considerable heat loss due to wastage of condensate and hot water from processing operations, which, if possible to reclaim, affords an opportunity to reduce the steam consumption.

Steam condensate that is not contaminated should generally be utilized as boiler feed. If the condensate is scattered over considerable areas, however, the cost of a return piping system to collect all of it may not be justified by the savings.

Heat in waste process water can often be reclaimed. Some processes require hot water, usually heated by steam, and any heat that can be reclaimed reduces the steam requirements. The practicability and economy of this form of heat reclamation usually involves a careful study of all conditions. There must be a considerable quantity of waste process water; heat content must be appreciable; chemicals and solid matter must not be present in objectionable amounts; and ample hot water storage facilities must be provided. Finally, the savings made must justify the cost of the heat-reclaiming equipment.

The higher the costs of materials and labor used in manufacturing the product, the greater the relative importance of the savings that can be made in power costs. Because wastes can be eliminated, power costs are an important part of controllable manufacturing expense. Modern equipment and methods constitute the waste removers

Waste heat in the form of hot gases from certain types of kilns and furnaces may often be utilized economically to generate steam or heat water. In cement mills the waste heat in gases from the calcining kilns is often sufficient to generate most of the steam requirements.

No general rules can be laid down as to when heat reclamation from process work is practicable and economical. Each installation is a special problem peculiar to itself and requires a careful study of all conditions to determine the limitations and economic possibilities. Obviously, heat wasted in any form is a direct loss that is reflected in fuel costs. Wherever a large portion of this loss can be reclaimed in usable form at moderate cost, the problem is worth serious consideration.

Where large quantities of hot water are used for process work, plenty of storage capacity is essential to provide reserve for production and to secure good efficiency in steam usage. Storage capacity serves as an equalizing heat reservoir in the system. Steam peaks are smoothed out to a large extent, thus reducing demands on the boiler plant. It is also necessary for securing the best results with any scheme of waste heat reclamation.

Automatic control of steam usage offers possibilities for the more efficient use of steam by regulating the amount to suit the requirements. In factories, automatic control of building heating is used to some extent, but in the great majority of cases control is by hand. It is left to employees to open or close radiator valves as they see fit. Radiators are often left on continuously, and windows are opened when the room gets too warm. Such conditions result in the use of much more steam than is necessary. Where they exist, some form of automatic control will increase comfort and improve efficiency in the use of steam. Usually the best results will be secured with zone control, which has the advantage of flexibility and permits control of each area to suit its requirements.

Unit heaters lend themselves particularly well to individual automatic control at small expense. Direct radiation can be controlled at less expense when arranged in groups. Controls are available for all conceivable conditions and arrangements.

The extent to which heating system controls should be used, will depend on the steam savings that are possible and on how closely it is desired to maintain the desired temperatures.

Use of automatic controls on process equipment using steam not only assures the maintenance of the close temperature limits usually required for uniform production, but also gives minimum steam consumption for a given production.

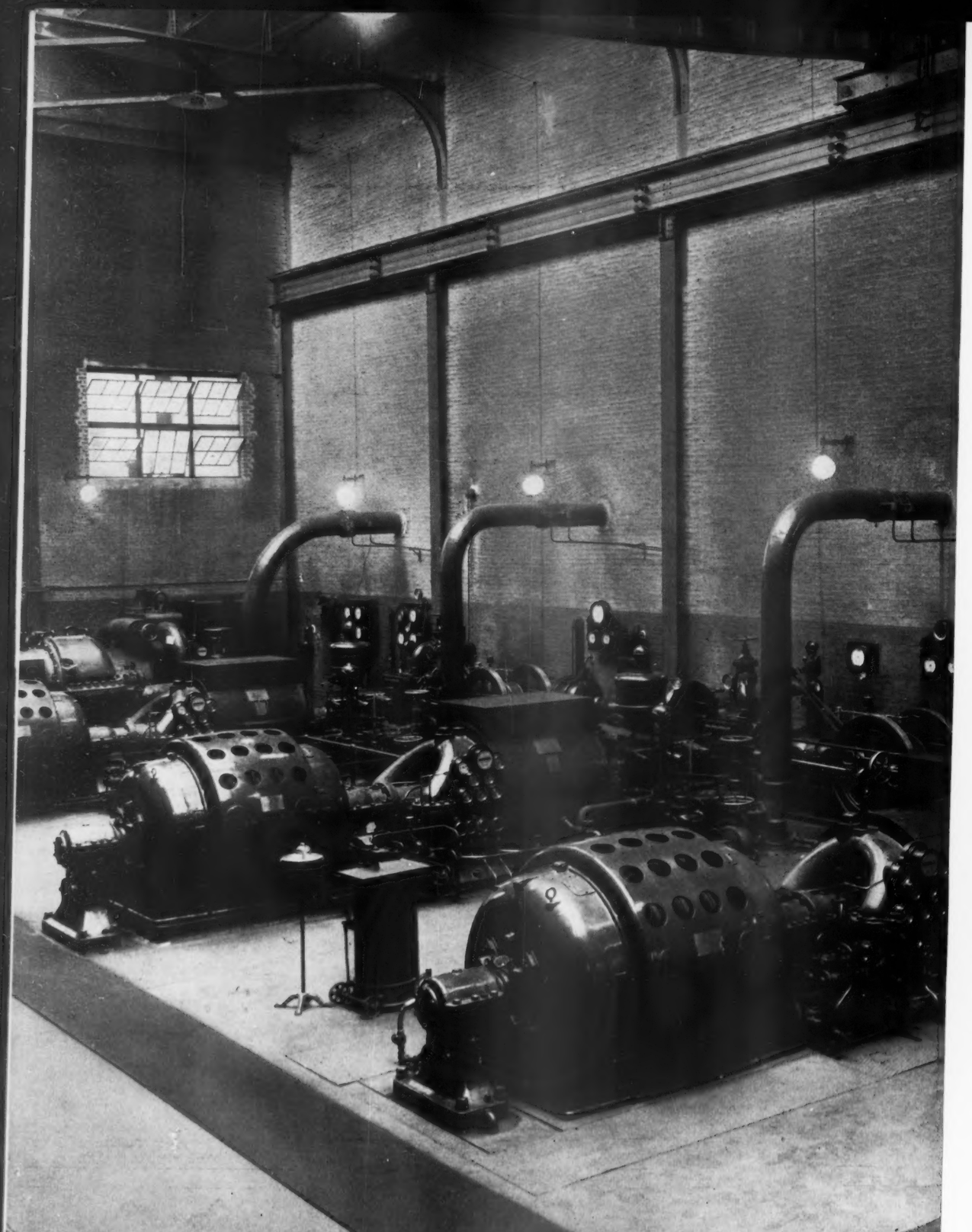
Control Steam Heating

In many processes open-end steam pipes or pipe coils are used for heating. Frequently there are a number of such units controlled by hand-operated valves. Usually valves are fully opened on a number of units simultaneously, causing an enormous rush of steam. If the boiler plant does not have sufficient capacity, the steam pressure drops, and production from other steam-using equipment is temporarily interfered with. Staggering the heating operations will help to avoid this condition, but may be undesirable from a production standpoint.

Much can be done to alleviate such conditions and promote more efficient use of the steam by putting in the supply lines orifices selected to pass a predetermined quantity of steam. Some form of regulating valve may be used, but an operator may change the adjustments and defeat the purpose for which it was installed. Orifices must be removed to be made ineffective, and they are not readily accessible for removal.

Recording instruments, judiciously selected and located, help to improve the efficiency of steam usage and maintain production standards. Permanent records from graphic instruments will show at a glance whether the proper conditions for process work are being maintained; if not, the situation can be remedied much more quickly than if no record were available.

Steam flow meters on important pipe lines are valuable in locating unusual steam consumption that may be caused by some defect in equipment or accessories, and which might otherwise go undetected for a long time.



Turbines for adaptability—a number of combinations of types and methods of operation can fit them for a surprising variety of conditions

FOR LOWEST POWER COST

Find the Cheapest Source of Electrical Energy

EVERY industrial plant has to have a supply of electrical energy, and the question of whether it is more economical to purchase or to generate that energy frequently comes up. The answer depends entirely on the conditions. As a rule, when there is small demand for exhaust steam, it is cheaper to purchase electricity than to generate it in a steam-driven plant. If a factory requires a continuous supply of low-pressure steam throughout the year, it can frequently generate its own power more cheaply than even the central station.

Such a result is possible because circumstances permit the attainment of a heat balance. In other words, the steam required to generate the necessary power is just sufficient to satisfy the requirements for process steam. No excess exhaust steam has to be wasted, and little, if any, live steam has to be used for process or heating. Therefore, when steam-driven equipment is used, the cost of generated power depends largely on the relative demands for energy and exhaust or low-pressure steam.

In few instances can a reasonably accurate heat balance be maintained throughout the year without some effort. During the winter most factories will require steam for heating the buildings; during the summer a corresponding amount of exhaust steam will be wasted.

Condensing Equipment

One method of balancing the production of exhaust steam against the requirements for low-pressure heating involves using condensing equipment and operating one or more of the generating units condensing in summer, non-condensing in winter.

Most plants do not have a natural supply of cooling water, such as a river or lake, for condensing operation. An alternative is a cooling tower or spray pond. Such an installation may show a good return by avoiding the use of city water except as make-up.

When reciprocating engines are operated non-condensing in winter and condensing in summer, readjustment of valve settings and possibly clearance volumes will be necessary. If turbines are used, such troublesome adjustments can be avoided by forethought in design.

Heat balance of an existing engine-generator plant can frequently be improved by the installation of an exhaust-steam turbine. It may drive one of the main generators or serve as an alternative source of power for some large, continuous, motor-driven load, such as a blower, line shaft, or other load of considerable size in proportion to the total.

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Such a turbine may be operated on excess exhaust steam only, at a pressure equal to the normal back pressure on the power plant, and may exhaust into a suitable condenser. Or it may be provided with a high-pressure connection that is automatically controlled and will admit high-pressure steam only if the exhaust steam available is insufficient to carry the load.

If the turbine is designed for best efficiency with exhaust steam, it will be wasteful of high-pressure steam. It is possible, however, to add a few stages of high-pressure blading ahead of the low-pressure portion, if high-pressure steam is to be used an appreciable portion of the time, and thus improve the over-all efficiency.

A so-called mixed-pressure turbine can be designed to meet still greater variations in the production of and demand for exhaust steam. Such a unit with a condenser can be operated as an exhaust-steam turbine in summer, when there is an excess of exhaust. In winter it can operate either straight non-condensing or as a bleeder turbine, depending on the demand for low-pressure steam.

Where no low-pressure steam is required, the diesel engine generating unit should be considered. Diesel units operate with the lowest fuel cost of any prime mover yet developed. Often they are the best choice in a plant that has a satisfactory heat balance, but requires additional power.

The efficiency of a diesel engine is nearly constant from full load to somewhat less than half load. Furthermore, efficiency of diesel engines rated 50 or 100 horsepower is as high as that of the largest units of several thousand horsepower rating.

Other valuable characteristics of the diesel are that it can be started at a moment's notice, and there are no standby losses while it is idle.

A diesel engine produces no exhaust steam, but the waste heat in the exhaust and in the jacket cooling water can sometimes be utilized. Together they account for roughly 70 per cent of the heat value of the fuel, and may be worth recovering.

Another means of improving heat balance in certain plants is the steam accumulator. It may be of value where exhaust steam is produced intermittently and is required in constant volume, or where the demand for high-pressure steam is subject to wide momentary fluctuations.

Hot Water Storage

Somewhat the same principle as the steam accumulator may be utilized in providing ample storage capacity for hot water heated by exhaust steam, when the demand is large, but extremely intermittent.

It is difficult to give average operating and installation costs of industrial power plants since fuel, labor, building, and other costs vary widely. However, some general figures may help in making a rough check of the probable cost of installing a plant and generating electricity. The following are average costs for the average factory power plant; in specific cases there may be a considerable variation in either direction:

In the average factory working 48 hours a week, with a fairly steady power load, 1 kilowatt of installed generator capacity will generate approximately 1,500 kilowatt-hours a year, allowing for a reasonable proportion of spare equipment. If a factory works more than 48 hours a

week, this annual output will vary in proportion.

A factory working 48 hours a week and purchasing 900,000 kilowatt-hours a year would need 600 kilowatts of generator capacity, if installing its own plant. The plant might consist of three 200-kw. units or two 250-kw. and one 125-kw., making it possible to shut down any unit for repairs. Of course, many single-unit plants operate successfully for years without interruption during working hours, but conservative practice calls for a spare unit.

If three or more units are installed, the investment in the spare unit may be minimized. It is often advisable to have a small unit for periods of light load.

Installation costs for the more efficient types of engine-driven generator units, with foundations, steam and exhaust piping, generator panels and wiring, will approach $100 a kilowatt in sizes up to 300 or 400 kilowatts.

For diesel engines this figure is about $100 to $120 a kilowatt.

Interest, taxes, insurance, and amortization should be figured at 10 per cent on the average factory power plant installation cost. On this basis the fixed charges per kilowatt-hour of current generated will run ½ to ¾ cent. To this figure must also be added the cost of fuel, labor, supplies, and repairs.

Fuel costs vary with the locality, but with average boiler conditions it may be assumed that 1 pound of soft coal will evaporate 10 pounds of water. If a noncondensing engine uses 40 pounds of steam a kilowatt-hour, 4 pounds of coal will be required to make the steam. On this basis, a ton of coal will produce 500 kilowatt-hours. Allowing for condensation in pipes and for lower efficiency under light loads, the average might be taken at 400 kilowatt-hours a ton. If coal costs $6 a ton, the unit fuel cost will be 1½ cents a kilowatt-hour.

In some plants where the mechanical equipment is elaborate and high-pressure steam is required throughout the year, little or no additional labor may be required to operate generating equipment. Elsewhere, one or more additional employees may be required. Their wages must be divided among the total kilowatt-hours generated during the year.

Thus, if an additional engineer receiving $2,500 a year is required, and the plant generates 1,000,000 kilowatt-hours a year, the labor cost will be ¼ cent a kilowatt-hour.

Supplies including oil, waste, packing, and ordinary repairs such as occasional reboring of cylinders and refitting of valves, may amount to 1 to 2 mills a kilowatt-hour.

Summarizing the above costs in cents per kilowatt-hour gives:

Fixed charges	0.60
Fuel	1.50
Labor	0.25
Supplies and repairs	0.15
Total	2.50

It will be seen that the fuel cost accounts for all but 1 cent of the total. It is difficult to reduce the items entering into this total, but the fuel cost depends almost entirely upon how much of the exhaust steam can be usefully employed. If two-thirds of it can be utilized, which is not unusual, the net fuel cost will be ½ cent, and the total cost of electricity will be 1½ cents a kilowatt-hour.

In determining power policy and procedure consider these questions: Shall power be made or bought? If made, what equipment is to be used—what fuel—how control waste? If purchased, how cooperate with the central station to keep bills low? In utilization of power, how control waste?

A diesel engine does not produce exhaust steam, but the fuel cost is low, probably below 1 cent a kilowatt-hour, so that the total of all the items listed in the above summary may be below 2 cents a kilowatt-hour.

Operating a steam engine or turbine plant condensing may cut the fuel cost in the average factory power plant approximately in half, but without leaving any exhaust steam available.

Plants located near coal mines, gas wells, or oil refineries may be able to obtain fuel at prices far below the figures used for illustration, and the results will be modified accordingly.

The problem of securing a heat balance does not consist merely of watching the exhaust head to see that no steam escapes. Every part of the cycle from the coal bunker to the returns receiver should be carefully analyzed. All high-pressure drips should be systematically collected and piped back to the boiler room. If large quantities of hot water or solutions must run to waste after being used, most of the heat can sometimes be recovered by a suitable exchanger.

Attention given to securing efficient combustion of solid, liquid, or gaseous fuels will yield greater returns than any other item around the factory power plant. Use of automatic stokers will materially increase the efficiency over hand firing, and in the larger plants the saving of labor will be considerable.

Control of excess air is important with coal, doubly so with oil or gas. Proper automatic combustion control apparatus with intelligent supervision will make possible important economies.

No Two Alike

Broadly, no two factory power plants are alike. Similar factories in different localities have widely varying fuel conditions. Climate varies throughout the country, and with it the heating requirement. One factory may have an ample supply of cooling water suitable for surface condensers. Another may require jet condensers to handle polluted water. Some factories may find it advisable to purchase a certain proportion of their electricity, generating only a part of it, or only during the heating season.

To secure the most economical results, all the factors must be carefully coordinated.

Simplicity and reliability are of the first importance. No apparatus or device should be installed to increase efficiency unless its use is fully warranted by the size of the plant and the possible saving that can be made.

Obviously, some of the methods and types of equipment used by modern central stations are not suited to the requirements of the average factory power plant, where simplicity and reliability are of the greatest importance.

FOR LOWEST POWER COST

Arrange for Flexible Distribution with Minimum Losses

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FEATURES of an economical distribution system in an industrial plant include transmission of electrical energy with low losses and voltage drop, flexibility for extensions to the plant or changes in machine layout, adequate reserve capacity for probable increases in load, and the lowest initial cost consistent with these qualities.

Factors that must be correlated when laying out a new system or revamping an old one are: Type of current available (direct or alternating), voltage and phase of current at source; type and size of plant served, type of service being installed (light or power), distance between source of power and load centers, amount of energy required at load center, future permanency of the system; type of distribution circuit to be installed, initial cost, types of control and protective equipment; and probable cost of maintaining the system.

Current Determines Layout

Type of current and its characteristics at the source largely determine the layout. D.c. and low-voltage a.c. systems can be handled similarly, but high-voltage, particularly three-phase, current calls for other measures. For present purposes the source of power will be defined as the utility company's service connection or the plant's distribution switchboard.

D.c. distribution involves low-voltage current, which makes the system rather expensive. Since alternating current is readily transformed from high to low voltage, the cost of a transmission system is less than for direct current. Design calculations for d.c. circuits are comparatively simple, whereas for a.c. they must also take into consideration the number of phases, power factor, inductance, and capacitance, which tend to increase voltage drop.

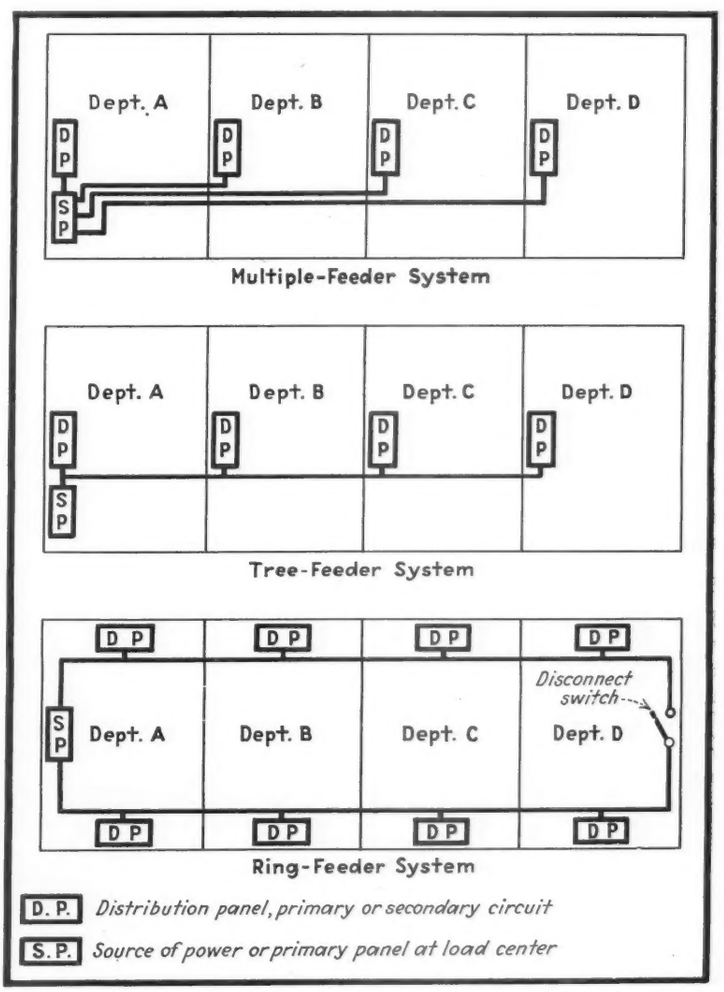
Type and size of plant will determine the layout of the circuits and whether it is advisable to divide the distribution system into a high-voltage primary and a low-voltage secondary circuit. A plant consisting of several buildings spread over a large territory is usually most economically served by the two-circuit system, whereas the small, compact plant is usually best served by a single-voltage system.

The function or type of service will also influence the layout of the circuit. The lighting system does not involve the same considerations as a power system. The two types of service should be kept on different circuits, except that fractional horsepower motors may sometimes be connected to a lighting circuit.

Distance between the source of power and the load center often determines the type of circuit, the method of installation, and the number and size of conductors.

Load centers can be readily placed, since the location of a building or department usually fixes the position of the distributing panel.

Energy requirements for each load center may or may not be known. However, a sufficient amount should be allocated to cover present needs with a reasonable reserve for the



future. Installing slightly larger feeders than initially needed, usually proves to be good economy, particularly if future developments bring additional loads.

Three Types of Feeder Systems

For the small plant the primary circuit, defined as that part of the system that connects the source of power to the various distribution panels, does not involve complicated considerations, since its voltage is usually the same as that used in the secondary circuit. Providing conductors of sufficient size from the source of power to the distributing panels is the most important matter. They should preferably be installed in rigid conduits and run as straight as possible to the panel.

The feeder system may be any one or a combination of three types of wiring. These three wiring systems are known as the multiple feeder, tree feeder, and ring feeder. Combinations of these may be made to cover almost any condition. The multiple and tree feeders, as a rule, are more flexible for primary circuits, whereas the ring feeder is satisfactory for secondary service.

Laying out the primary circuit for the large plant requires careful study, along with consideration of the secondary circuit connected to each primary feeder. Location and energy demands of the several load centers will usually determine the layout and design of the primary feeder circuit.

Feeder circuit conductors must be of the proper size in order that: (1) Electrical energy may be carried without excessive voltage drop; (2) energy loss in transmission (I^2R *loss*) may be kept at an economical minimum; (3) overheating and damaging of the insulation may be prevented.

Distribution at High Voltage

When high-voltage current, single or polyphase, is available at the source of power, and the distance from the source to the distributing panel is considerable, it is more economical to transmit the primary current at high voltage to a transformer bank adjacent to the panel. Whenever possible, the use of three-phase current is preferable. Care must be taken to balance the lighting load on each phase.

The transformer bank may be a single three - phase transformer or three single-phase transformers. The former is cheaper in first cost, but in the event of trouble service is interrupted until repairs or replacements can be made.

Three single-phase transformers give greater flexibility. If connected delta-delta and one transformer becomes defective, the remaining two may be operated open-delta or V-connected at 57.7 per cent of the original capacity. However, some engineers prefer the Y-delta or delta-Y connection, because of the possibility of grounding the neutral wire.

Overhead or Underground?

Primary circuit wiring may be installed overhead or underground. The overhead system has the advantages of lower first cost, greater overload capacity, greater flexibility. Disadvantages are higher maintenance cost, less permanency, possible damage by lightning, unsightly appearance, safety hazard, and danger in the event of fire.

Underground systems have the advantages of lower maintenance cost, permanency, and freedom from damage by lightning, whereas disadvantages are higher first cost, lower overload capacity, and less flexibility. However, the underground system will usually prove the more economical over the years.

Primary circuits should be laid out to permit adequate tying in or isolation of all or parts of the circuit by suitable switchgear.

Plant circuits should provide adequate facilities for future changes and growth, which requires close cooperation between production and maintenance.

Secondary circuits serve both lighting and power equipment. Each type of service requires different treatment. Current characteristics of the secondary circuit depend upon the supply. Unusual characteristics are: Lighting circuits, 110/220-volt, three-wire, balanced system for either direct or single-phase alternating current; power circuits, 220-volt, two-wire, direct, and 220- or 440-volt, three-phase, alternating current. The usual voltage drop allowed between the source of power and the equipment is 2 to 4 per cent for lighting systems, 5 per cent for power systems.

Makers of power equipment, for generation, transmission, and utilization, have increased the efficiency of their products. During the time of low volume in manufacturing, power equipment engineers have continued their development work, now have the results available

Layout of Light and Power Circuits

Lighting circuits and their layout require a thorough knowledge of good lighting practice and careful consideration of the occupancy of the area. Conductors should have ample capacity to minimize voltage drop and provide reserve for load increases.

Layout of power circuits requires more thought and care than layout of lighting circuits. Since shifts in equipment and load are frequent, both present and probable future needs must always be kept in mind.

Wiring for the secondary system may be laid out according to the designs previously mentioned. Conductors can be placed (1) in rigid conduits, with junction boxes located at short intervals for convenient tapping; (2) in metal ducts with knockouts for tapping; (3) properly protected busbars may be used, with branches tapped in at almost any point. Use of solderless connectors makes the tapping of mains easy, without damage to the wires.

Special care must be taken when installing wiring in areas where the atmosphere is humid, dusty, or polluted with corrosive fumes. Any one of these conditions increases the installation and maintenance problems and costs.

Protection of all electrical circuits and equipment is of prime importance. All elements should be protected so as to localize any faults due to overloading or short-circuiting.

Metering of service to specific areas or equipment is desirable, since it helps management to determine and control production costs. Adequate metering facilities should be installed whenever it is economically sound to do so.

FOR LOWEST POWER COST

Plan and Equip for Correct Utilization of Energy

EFFECTIVE utilization of electrical energy—in other words, getting the most work out of each dollar spent for current—involves several widely diverse considerations. For the present it will be assumed that if power is purchased the form of contract is suited to the class of service, and that the plant distribution system has been properly laid out and is adequate.

With these conditions granted, it is still possible for a plant to fall far short of getting the most per dollar spent for energy.

The bulk of the electrical load in most plants is in motors, largely the squirrel-cage induction type. All motors attain their highest efficiency when loaded close to rating. This is particularly true of induction motors. When designed for operation at 1,800 r.p.m. they are more efficient than those designed for lower speeds. Hence the use of 1,800-r.p.m. motors, whenever possible, and proper loading tends to assure minimum losses. Also, power factor will be higher.

Select Proper Motor and Control

Squirrel-cage motors are essentially constant-speed machines and require only a simple controller or starter. When conditions permit these motors are started across the line, or on full voltage. If this method is not suitable a compensator or other type of starter is used, which permits the motor to be started on less than full line voltage. Any effect that the method of starting exerts on motor efficiency is so transient that it can be disregarded, although the rush of current at starting is frequently of importance.

From other standpoints, however, the character of the control merits careful consideration, since it may affect the over-all efficiency to a high degree. Aside from starting and stopping its motor, the controller must protect it from injurious overloads. At the same time it must not permit temporary overloads or disturbances that will not cause damage, to interrupt service. This calls for a time-delay overload device. The control should preferably also embody low-voltage protection, to prevent unintentional starting when power service has been restored after an interruption.

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Factory Management and Maintenance

In many instances it is required that the driving motor operate at more than one fixed speed. Again, operation over a wide range of speeds may be required. When these variations in speed are obtained through the use of a resistance, as by the use of a d.c. motor with armature control, or a slip-ring-type a.c. motor, there is considerable wastage of energy in the form of heat dissipated by the resistors. Although these methods of obtaining speed variation have their place, it is well to avoid using them when the desired results can be accomplished in other, more efficient ways.

Methods of mounting or location of motors and the type of inclosure have a more marked effect on efficiency and maintenance costs than is sometimes realized. When production machines are individually driven there is a strong tendency to mount the motors on or near the floor. In this location they are exposed to falling water, metal chips, and foreign material of all kinds. Therefore, when open-type motors are used failures may be frequent. Merely mounting the motor on top of the driven machine, or a few feet from the floor, may practically eliminate winding failures.

The same general situation prevails when large amounts of lint, dust, fumes, or other harmful agents are present in the air. In all such cases the advisability of using fully inclosed, fan-cooled motors should be carefully investigated.

Means used for transmitting power from motors to machines exerts a very definite influence on the efficiency with which electrical energy is utilized. Mechanical power drives that are poorly laid out, inherently inefficient, not suited to the service, or carelessly maintained, can waste large amounts of power. Specifically, of the total power input to induction motors that drive production machines anywhere from about 13 to 60 per cent is lost between the motor terminals and the driven shaft.

These losses can be drastically reduced by taking advantage of the advances made during the past few years in power transmission equipment and the methods of application.

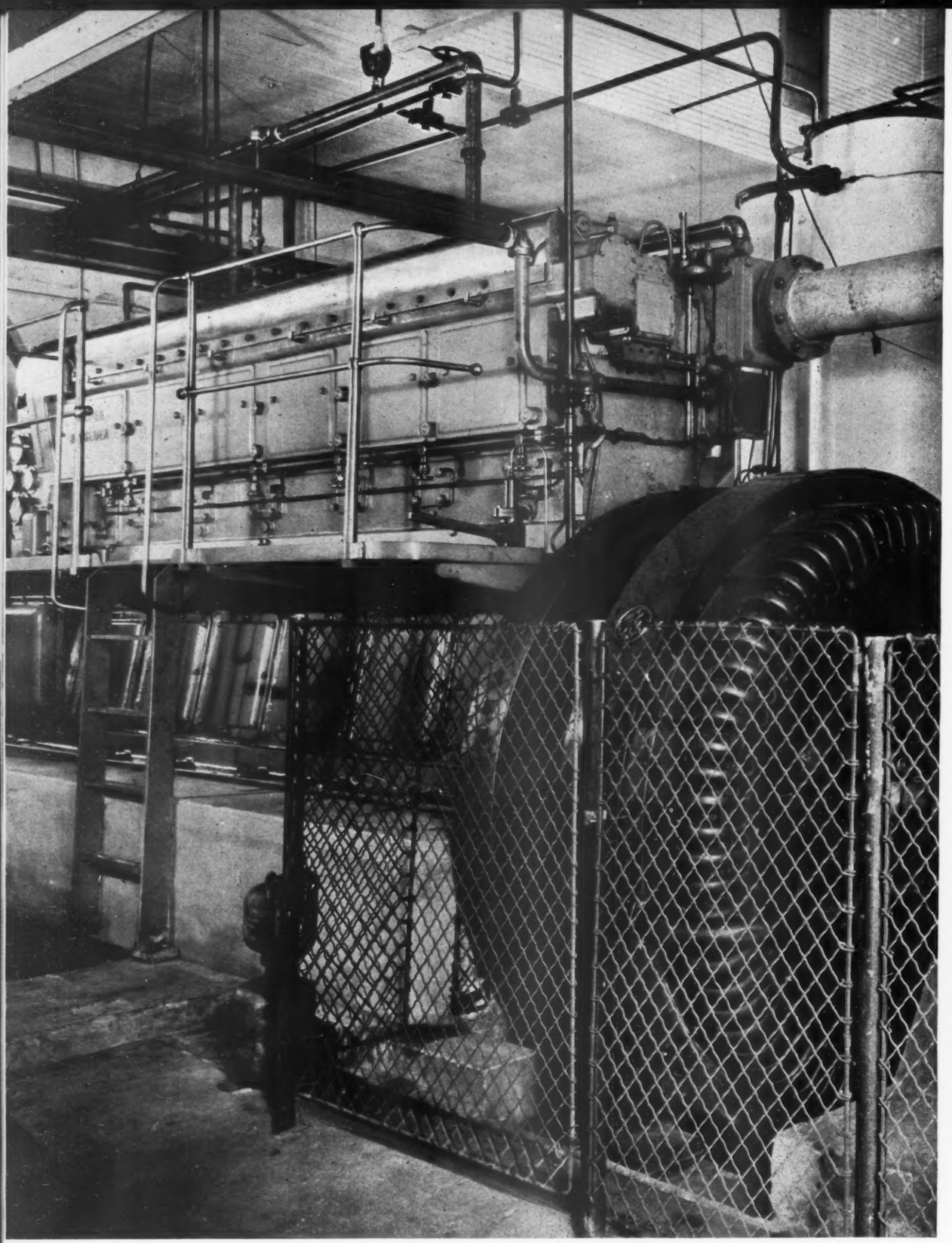
Low Power Factor, Less Capacity

Maintenance of proper electrical conditions in the distribution system is closely linked with efficiency of usage. Power factor is one of the most important of these conditions. The meaning of power factor can be appreciated more easily if it is realized that current flowing in any a.c. circuit which supplies induction motors, transformers, and other equipment that operates through an electro-magnetic field is made up of two components.

One component produces the required magnetic field; the other component is the current that is converted into mechanical energy or heat, as in the case of electric arc or induction furnaces. The relation between the total power in the circuit and the power that does useful work is termed the power factor.

Since the current component that produces the magnetic field in a piece of a.c. equipment does not represent an actual consumption of energy, it is referred to as the magnetizing or wattless current. However, it uses up capacity of conductors and other equipment and produces in general the same effects and losses as the working or energy current. Therefore, generators, transformers, and distribution lines may be loaded to full capacity, but only a part, say 60 or 70 per cent, of the total current is doing useful work.

Induction motors are the chief causes of low power factor in in-



275-hp. Cooper-Bessemer diesel installation, Gas Products Company, Columbus, Ohio

One of the important services of the diesel is to supply power where process and heating steam requirements are not controlling factors

dustrial plants. The power factor of these motors is around 90 per cent at full load, but it drops off rapidly as the load diminishes and reaches a value approaching 25 per cent when the motor is running idle.

Corrective Measures

Obviously, low power factor is undesirable because it places a nonproductive load on all of the generating, transforming, and transmission equipment, thereby reducing the capacity, increasing the losses, and leading to excessive voltage drop.

When energy is purchased low power factor, by increasing the load on the utility's equipment and lines, in effect ties up an unnecessarily large proportion of the capacity. Hence, industrial customers having low power factor are frequently penalized for it by direct penalties, payment of a bonus for high power factor, or by calculating demand on a kva. basis.

Measures for raising power factor are of two general types: preventive and corrective. For example, much can often be done by proper selection and loading of induction motors. With small motors, use of the capacitor type may be advisable.

Positive correction of low power factor can be accomplished by the use of synchronous motors to carry all or as much of the mechanical load as may be necessary; by the use of synchronous condensers floated on the line without carrying mechanical load; or by using static condensers, commonly referred to as capacitors. Selection of the most suitable method or combination of methods for correcting power factor must be based on a thorough study of the conditions and calculation of the return on the investment required with each method.

Opportunity to make important savings in the cost of power frequently is found in the correction of power factor. Instances are legion in which industrial plants have saved anywhere from a few hundred to several thousand dollars a year on their power bills by raising the plant power factor to a high value. These savings represent the elimination of penalty charges, reduction in demand charges, or both.

Incidental benefits of power factor correction may be almost as important as dollar savings. Included are lower line losses and voltage drop, less heating and better performance of motors. Moreover, instances are not lacking in which release of generator, line, and transformer capacity by raising power factor has made unnecessary the installation of additional equipment.

It will be apparent from the preceding that demand charges and power factor often bear a close relationship. Sizable savings may, however, result from measures to keep demand down, when the power factor is of satisfactory value.

This outcome is possible because the most common form of contract for the purchase of electrical energy is based on a rate schedule that embraces two separate charges. One is a graduated demand charge, the other a graduated energy charge.

The demand charge represents the utility's fixed cost of doing business, interest charges, and so on, for the investment in generating and other equipment required to maintain service at the customer's plant.

On the other hand, the energy charge covers the current actually consumed. Schedules are commonly drawn up so that the unit cost of energy decreases as the amount used goes up.

Demand is measured by a graphic meter over a period ranging from 5 to 30 minutes, or it may be determined from load conditions prior to the drawing up of the contract. Several methods are employed in determining the demand used as a basis for billing. For example, it may be based on the highest average rate of demand for 15 or 30-minute intervals during the month.

Cut Demand to Reduce Cost

Obviously, if high current peaks can be avoided, the demand charge can be reduced. Since high peaks are usually caused by the simultaneous starting or operation of two or more large motors or other equipment that imposes a heavy load, proper scheduling of operations will often markedly reduce demand peaks.

Demand-limiting devices are available that will, under the proper conditions, automatically keep current peaks within a predetermined value. These devices function by cutting off selected electrical loads when the plant demand reaches the maximum desired value.

Use of off-peak power also not infrequently presents an opportunity to reduce power bills considerably. When operating schedules can be arranged to take full advantage of the lower rate that can usually be obtained for energy consumed during periods when the load on the utility is light, the resultant savings may be large.

Resistance welding machines often present a serious problem in that they impose a single-phase load that has low power factor and a high demand that fluctuates from zero to maximum at short intervals.

A combination of reactors and condensers can be used to balance the load on a three-phase line, but the power factor will not be raised. When correction of the power factor is desired, it is advisable to supply the machines from an m.-g. set comprising a single-phase generator driven by a high-slip induction motor with flywheel, or a synchronous motor. Choice of the type of motor will depend on the characteristics of the load. This arrangement will give a balanced three-phase load of fairly high power factor and low peaks.

Ways to Avoid Waste

With electric heating loads of any considerable magnitude there may be an opportunity to effect worthwhile economies in power consumption. Heat insulation and proper control of operation are important factors. Well-designed ovens and furnaces have the correct amount and kind of insulation; home-made equipment may not have, in which event it will be wasteful of expensive heat units.

When conditions permit, energy consumption can be reduced by having the charge leaving the oven or furnace give up part of its heat to the incoming charge.

In any event, close temperature regulation and control of operation are essential to economical usage of energy.

When power is metered on the primary or high-voltage side of the transformers, the losses in them have to be paid for at the regular rate. If the transformers are large, investigate the feasibility of cutting them off the line during periods of shutdown. Usually a comparatively small transformer or bank will handle the load at such times.

Prevention of waste through operation of motors, lights, heating devices, and so on, when they are not required, is largely a matter of education and supervision. With large lighting installations, the use of photo-tube control may result in sizable savings, and at the same time improve lighting conditions.

FOR LOWEST POWER COST

Avoid Losses in the Mechanical Transmission of Power

TWO GENERAL systems have been developed for transmitting power from the prime mover, usually an electric motor, to the driven machine. In one system, commonly known as individual drive, each machine has its own motor, which may or may not be built into the machine. The other system, group drive, involves driving two or more machines from a common lineshaft.

Each of these systems has its advantages, limitations, and proper field of application. The fact that in many instances either system can be used, necessitates a careful study of the layout and operating conditions, with a comparison of the relative costs and advantages of the two methods of driving, to insure selection of the economical one.

A Motor for Each Machine

In general, individual drive permits changes in machine layout to be made with greater ease and at less expense than when group drive is used. Wide ranges in speed variation and close control of speed are obtained more easily. It permits greater flexibility in operation, since only the machines that are needed have to be operated. Space above machines is clear; hence there is no interference with overhead cranes, conveyors, or other equipment. Failure of a motor does not necessarily reduce production seriously.

On the debit side are the facts that in a typical plant the total first cost for an individual drive installation will be, roughly, from 80 to 200 per cent more than for a corresponding group drive. Total annual cost, including fixed charges, will be around 25 to 50 per cent higher than for group drive. Use of comparatively small motors that usually operate considerably underloaded, results in a low plant power factor.

It follows from what has been said above that group drives that are properly designed and installed are considerably cheaper in first and annual costs. Use of one large motor in place of a number of small ones permits loading much more nearly to rating, with resultant greater efficiency and higher power factor. Large motors are more rugged, hence less likely to give trouble. When machines are driven in a group, a large reserve of power to handle momentary peak loads on one or more machines is available.

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Limitations include less flexibility than provided by individual drive for changes in layout; necessity of operating more equipment than is needed when only one or two machines of a group are in use; curtailment of the effective operation of cranes and other overhead equipment; group shutdown if the driving motor fails.

As a rule there is little question that individual drives should be used in areas requiring overhead crane service; on machines that would require countershafts if operated in a group, and that are likely to be moved frequently; on machines that require considerable power (20 to 30 hp. or more) and impose a fairly constant load; on machines that are scattered over a large area; on machines that must be located at various angles.

On the other hand, group drive is most suitable from an operating standpoint when the power required to drive the machines is highly variable, with occasional extreme peaks of some seconds' duration, and when the machines are in more or less constant operation.

In many instances the nature of the driven machine, its location, or the service conditions will clearly indicate the most suitable type of drive. This is particularly true of machines that are best driven individually. In a large percentage of cases, however, either type of drive can be used, and choice between the two must be based on production considerations and relative initial and operating costs.

Production considerations, which will vary with different plants and with the industry, lead into too many ramifications to be discussed here. Suffice it to say that the effect on production of the delays due to breakdowns merits careful study.

It is not to be supposed that all the machines in a plant, or even in a large department, will ordinarily be driven individually or in groups. In the average plant of any size, individual drive will almost certainly be indicated or required for some machines, whereas others will just as obviously be best driven in groups. The problem is to select the most suitable and economical method of driving each machine.

Proper design of drives is highly important, regardless of the type or system chosen. With individual drives, direct connection of the motor to the driven machine is frequently possible. In most instances, however, reduction in motor speed is necessary. Therefore, a motor with inbuilt speed reduction unit will be employed or power will be transmitted from motor to machine through a separate speed reducer, chain, variable-speed device, or belt. As a rule, the use of open gearing that is not an integral part of a machine should be avoided.

To Reduce or Vary Speed

With speed reducers or geared motor-reducers, practically any desired ratio of reduction can easily be obtained, and they are widely used.

In a good many instances it is required that the speed of the driven equipment be varied over a fairly wide range. This can be provided by using one of the several different types of variable-speed transmissions, or adjustable- or variable-speed a.c. or d.c. motor.

Chains are often used as the drive medium. They are made in three general types—the malleable iron, detachable link; the unfinished steel roller; and the finished steel roller chain. The first type is comparatively inexpensive and suitable for driving light machinery when the speed does not exceed 400 f.p.m.

For moderate loads and where the speed is not above 600 f.p.m., an unfinished steel roller chain is usually satisfactory.

Transmission of large amounts of power at higher speed requires use of a finely made chain, operating on cut-tooth steel or cast-iron sprockets.

Chains are widely used when moderate reductions in speed are required. Rugged and reliable when properly applied, they provide a positive, non-slipping drive little affected by temperature, that would soon destroy any organic belting material.

When Belts Transmit Power

In a large proportion of individual drives a flat leather or rubber V-belt transmits the power. The latter type of belt consists of one or more V-shaped strands of rubber and fabric composition, running in grooved pulleys. Unlike the drives previously discussed, short-center belt drives provide a cushioning effect that helps to smooth out shocks. If the machine jams, the belt, particularly the flat type, will usually slip off or break and thus may prevent extensive damage.

Considerable trouble was formerly experienced with short-center drives from the difficulty in maintaining proper tension, to avoid excessive slippage and burning of the belt. There are now available pulleys made of paper or other material having a high coefficient of friction, well-designed idler pulleys, and pivoted motor bases that permit part of the weight of the motor to be utilized in maintaining the correct tension in the belt under all conditions of load. These developments make it possible to design short-center drives that will have satisfactory life and operate with the minimum of trouble.

Proper selection and correct design of individual drives are highly important factors in securing trouble-free operation, long life, and low losses. Drives should be designed liberally, to allow ample margin for the high stresses encountered during starting and under peak loads. Remember that the starting torque of present-day induction motors may be four or five times the rated full-load torque.

Another cause of serious trouble is the tendency to mount motors on or near the floor, where they are exposed to water or oil, metal chips, and all manner of waste material. A large proportion of the failures of open, low-mounted motors result from the entrance of foreign matter. Much trouble can be avoided by mounting motors as high as possible.

In the group drive system, power is transmitted to the lineshaft usually by a belt, although in many instances a chain is used. The machines are driven by belts.

Lineshafting is usually cold-rolled steel, although nickel-steel and vanadium-steel shafting are used to some extent because of their greater strength, toughness, and ability to resist fatigue and shock. Plain bearings are popular on lineshafts. When well designed and properly lubricated they give satisfactory service at moderate speeds. Ball or roller bearings are also widely used, particularly on high-speed shafts. Along with lower starting friction, they require less frequent lubrication.

Several types of belting are available for various service conditions. Leather is most widely used under average plant conditions, and can be obtained in several different tannages and types, including waterproof. When exposure to steam, water, oil, or fumes is severe, some type of fabric belt is often used. There are a number of varieties of such belts, which are made up of plies of cotton duck. These belts are usually impregnated with rubber or other material to prevent ply separation, increase the strength, and make the belt more or less resistant to moisture and other agents.

Notable improvements have been made during the past five years in all types of belting. Selection of the correct type, particularly when the operating conditions are severe, is essential to low-cost operation.

It is only the very new power plant that will not permit worth-while economies. In most plants an engineering survey is in order. When a survey is made, costs must be investigated all along the line right to the point of application where useful work on the product is done

In laying out group drives, observance of several simple principles will do much to reduce losses and insure efficiency. Size and arrangement of groups will be dictated largely by production considerations, obstructions, and so on. It is a mistake, however, to make drive groups either too large or too small.

In the one instance the groups become unwieldy. When only a few machines are required to meet production needs, the electrical and friction losses reach uncomfortable proportions. Also, failure of the motor stops too many machines.

Too small groups result in a heavier investment in motors, use of larger motors than would otherwise be required to operate the same number of machines, and an increase in motor losses.

Commonly from eight to twenty machines to a group, depending on the length of shaft needed and the power required by each machine, will give the best efficiency.

Anti-fraction bearings are advisable in countershaft hangers and loose pulleys, desirable on line shafts.

Cross belting two or more parallel shafts in order to operate them from one motor should be avoided. Use a separate motor for each shaft.

If vertical belts must be used it is advisable to employ some device for maintaining the proper tension.

Loss of power through belt and pulley windage is far from negligible when belt speeds are more than 4,000 or 4,500 f.p.m. It had long been assumed that the most efficient belt speed was around 4,000 or 5,000 f.p.m.; now it is apparent that, from the standpoint of low power losses, the best belt speed is closer to 2,500 than to 4,500 feet per minute.

Finally, when standard open-type motors are used they should be mounted high enough so that water or falling material cannot enter. It is important to leave a clear space underneath the motor, to facilitate oiling, inspection, and replacement.

Considerable amounts of power can be and are being wasted in poorly designed, carelessly maintained power drives. These losses can be drastically reduced by taking advantage of the better designed equipment and greater knowledge now available.

FOR LOWEST POWER COST

Check Lubricating Practices to Find Power Losses

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AMONG the many factors adversely affecting the efficient use of power is friction. While design, condition of equipment, and operating conditions have the greatest effect on power consumption, the quality of the lubrication governs the friction loss in any particular machine.

Lubrication affects not only power consumption, but maintenance cost, oiling labor cost, and cost of lubricants. It also affects quality of the product, safety, and the continuity of production.

A plant engineer may take pride in his low maintenance costs, and consider that his operating practices have lowered power costs to a minimum, yet may not know that every gear case in the factory is overloaded with lubricant which is so cohesive that it creates an excessive demand on the motor. The air and ammonia compressors may be feeding a heat-insulating film of oil to the intercoolers, ammonia condenser, expansion coils, or brine cooler. True, his maintenance costs may be low, but through too close attention to this factor he has failed to practice economy in power consumption.

Where should the plant engineer search for power loss caused by incorrect lubricating practices?

Use of Lubricant Unsuitable for Operating Conditions

As a class, operating engineers show a preference for heavy or viscous oils. The oil which has body and feels thick or "fatty" between the fingers is at once pronounced to be a good oil, whereas the oil of low viscosity, lacking this fatty feeling, is at once condemned as a poor oil—"just like water." As a result of this widespread misconception much heavier oils are in use than is necessary.

Petroleum oils have that most desirable characteristic of adjusting their viscosity to the operating conditions. If too heavy an oil is used for proper distribution in a plain bearing, imperfect lubrication during the starting period will generate heat and lower the viscosity until proper distribution is maintained. This adjustment in the viscosity has caused wear and power loss.

Where machinery is subjected to outdoor temperatures, lubricants should be changed at the beginning and end of the winter months, to avoid power loss and wear. Such equipment as elevators, conveyors, pumps, ventilating fans, and yard equipment should be lubricated with low-cold-test oils or greases during the winter months. Occasionally these lubricants will prove satisfactory for summer service.

In the lubrication of inclosed transmissions the use of a semi-fluid grease or extremely viscous oil may properly shield the gears or worms, whereas bearings, if plain, may be inadequately lubricated. This condition is easily detected by the excessive temperature of the bearings.

Heavy, compounded oils or semi-fluid greases tend to hold metallic cuttings and abrasives in suspension where they will do the most damage, whereas oils of lighter viscosity permit these elements to settle.

Greases, although satisfactory for sleeve-type bearings operating up to 500 r.p.m., are not economical at high speeds.

Influence of Lubricating Devices on Power Consumed

The function of a lubricating device is to deliver an adequate supply of lubricant to the bearing while in operation. Where equipment is operated days only, or intermittently, some devices in common use do not supply sufficient oil until after the machine has reached operating speed.

Bottle oilers supply a need and are economical of service required and oil consumption. Bearings lubricated with bottle oilers often lack an adequate supply of lubricant at the start. This may also be true of sight-feed oil cups, if improperly operated. These oilers are provided with a snap lever which if raised only half-way permits the oil to run in a greater quantity than is permitted by the valve adjustment which regulates the flow. Either through lack of instruction or carelessness this feature is not used.

Ring-oiled bearings may be inadequately lubricated at start if too viscous an oil is used. This is particularly true where oil is subjected to low temperatures. The oil congeals and in this condition prevents the ring from turning. Damaged rings often fail to turn and supply the required amount.

Probably most of the wear in plain bearings occurs during the starting period.

Servicing Machinery

Only through proper instruction and education can proper lubricating service be obtained from operators, oilers and operating engineers. Specific instructions should be given as to the lubricant to use, the method of operating the lubricating device, and any precautions that should be taken.

For intermittent service where bottle, wick-feed, or sight-feed oilers are used, operators should be instructed to flood the bearings with oil before the machine is started. If bearings require hand oiling (with an oil can), it should be done before the machine is started.

Conservation of power and prevention of wear require attention to oil levels in gear cases. Many constant-level oilers are on the market which provide a reliable means of controlling the level.

Frequency of service required should be established for each bearing or part, not left to the oiler's judgment.

Wasted Power Through Contamination of Lubricant

Where machinery operates in an atmosphere containing coal dust, sand, dry chemicals, lint, and so on,

adequate sealing of the bearings is important. If mechanical shielding is impossible the use of grease may be helpful. Greases generously fed to bearings form an effective seal.

Contamination of lubricant with solvents, water, or chemicals may cause failure of the film. Use of lubricants containing graphite is recommended where contamination is likely. On plain bearings of centrifugal pumps handling hot water or solvents, graphited greases should be used, provided the graphite is not undesirable in the liquid. The graphite will prolong the life of the bearings by providing a solid lubricant where the oil or grease has been swept away.

Carbonaceous Deposits

Efficiency of air or ammonia compressors and internal combustion engines is greatly reduced by carbonaceous deposits on valves and piston rings. Failure of the valves to close properly, or the piston rings to seal properly, results in a loss of compression and lowered efficiency.

Deposits in discharge pipes of air compressors reduce the inner diameter of the pipes and restrict the flow of compressed air. This causes incomplete displacement of the compressed air and recompression takes place in the cylinder, causing a marked increase in the temperature of the compressed gas and the cylinder. The result is lowering of efficiency and creation of an explosive hazard.

It is, therefore, advisable to use oils having a low carbon residue, a high degree of stability, and resistance to emulsification with water.

Relative stability may be determined by testing oils before and after performance tests to determine the degree of change in the physical characteristics.

Resistance to emulsification is determined by the emulsification and demulsibility tests, the former determining the degree to which an oil will emulsify, whereas the latter shows the rate at which an oil will separate from water.

Impaired Heat Transfer

Efficiency of refrigeration equipment is decidedly affected by the quality of the cylinder lubricant, the amount fed, and the means of trapping the oil before it reaches the condenser. Entrained oil will pass into the condenser, reduce its efficiency, and reach the expansion coils or brine coolers, where its presence reduces the rate of heat transfer.

Also, unless a low-cold-test oil is used it will congeal in the pipes and necessitate shutting down the machinery to raise the temperature so that the oil will flow and may be removed.

Non-condensable gases, composed of air and oil vapors, also reduce the efficiency of refrigerating equipment. It is, therefore, necessary to use a cylinder lubricant that is stable and does not volatilize. In comparing lubricants they should be tested for volatilization.

Machinery Failures Wrongly Attributed to Lubricants

When bearings fail or equipment operates inefficiently, the lubricant is the first consideration in searching for the cause. Too often it is blamed for failures that are caused by mechanical conditions. Among the mechanical conditions that often cause failure of bearings or inefficient operation are misalignment, overloading, poor condition of piston rings or ring grooves, stuffing boxes or packing drawn too tight, belts too tight, and extreme overloading of bearings and parts by improperly aligned gears.

The failure of ball bearings is often wrongly attributed to the lubricant. Each ball bearing has its individual service life and all the honest efforts of manufacturers to produce bearings of equal service life have failed. The operating engineer or maintenance man may point to bearings of the same size and make, operating under the same conditions, and say, "It must be the lubricant that caused the failure, because the bearings on the other machine have been in service longer than these, and are operating satisfactorily."

Such an argument is expressed without a full knowledge of the individuality of ball bearings. All that can be said is that the bearing which failed probably had from the beginning a shorter service life than the others.

Often the lubricant is blamed for the short service of a ball bearing when the cause of the failure is a rapidly fluctuating load which is pounding the bearing. Motors, fans, pumps, and centrifugals, often pound bearings until failure occurs.

Machines, babbitted bearings, and other parts have individual characteristics that affect their performance. Do not necessarily expect the same service life from two babbitted bearings poured by the same man, on the same day, and machined in the same way. If failure or unusual wear occurs after a reasonable period of service, and the bearing was lubricated properly, the chances are greatly against the lubricant as the cause of the failure. Probably the real cause is fatigue or some change in the metal structure.

Attention to Lubrication is Profitable

Steel and textile mills have reported savings in power consumption amounting to 10 per cent of the power cost where lubrication requirements have been studied.

To the lubrication engineer, reduction in power consumption is but one of many factors that are influenced by the quality of the lubrication service. He must consider protection of the bearing or part to insure low maintenance cost. In many industries contamination of the manufactured product must be prevented either through design, the installation of oil seals, or the selection of the lubricant. Continuity of production must be insured by equipping machinery for adequate and proper oiling while it is in operation.

Cost of lubricating service, the cost of lubricants, and the effect of lubricating practices on safety must also be considered. The importance of all of these factors must be recognized in order to insure the most satisfactory results.

Management is responsible for the elimination of power wastes. The power engineer in the plant can do part; the power consultant can do part; the electrical and mechanical engineers can do part. But the over-all responsibility is management's

For effective, low-cost utilization of electrical energy: First, the proper equipment; then continual analysis of where the current goes and what it does

FOR LOWEST POWER COST

Survey Power Conditions in Your Plant and Correct Accordingly

IT IS axiomatic that only the most minor changes should be made in the steam and power generating equipment of an industrial plant, when full knowledge of the equipment and operating conditions is lacking. Failure to observe this principle may result in expensive, even ludicrous mistakes. Certainly, any important changes in load or equipment should be planned and executed only after a thoroughgoing survey of the entire installation.

Such a survey may also be required in order to determine possibilities that lie in the existing plant; to form a groundwork of facts on which to base recommendations for economical betterment; to meet intelligently conditions that require replacement of equipment or expansion of facilities; or as the basis for the design of an entire new plant.

Under any of these situations it will be necessary to develop plans that will amply justify the expenditures called for.

The whole field of industrial heating and power generation and application covers such a wide variety of equipment, the detailed problems which they present and their solutions are so diverse that nothing more can be attempted here than to outline the most essential data needed for a study of the problems and conditions in average typical plants.

It's a Big, Difficult Job

Intelligent planning, painstaking execution of the work involved in making a survey are prime essentials in the securing of adequate and reliable data. Work that is rushed through by personnel which is incompetent or hampered by lack of proper instruments and facilities is likely to be worthless, or worse; it may lead to erroneous conclusions that in turn are the cause of expensive mistakes.

One of the first decisions to be made covers the extent of the study required. That question is directly related to the purpose of the study. For example, instances are frequent in which it becomes necessary only to make a choice between two or more alternate types of equipment, such as a turbine-driven and an engine-driven generating unit, or between stoker firing and pulverized coal. In such instances the scope of the study is naturally so limited that only a few of the values in the accompanying tabulation of data are needed. Those that are required to form the background for an intelligent decision can easily be selected.

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On many other occasions a complete survey will be required in order to obtain the data that are necessary when radical alterations or extensions are in prospect.

A considerable proportion of the data called for in the tabulation should be available from operating records. In such cases care must be taken to use figures covering a sufficient period of time to insure true average results. The remainder of the information needed will have to be obtained by actual tests or measurements.

Details of the exact procedure in making the various tests are given in many text and handbooks and need not be recounted here. It is important, however, to make all tests under such conditions and over a sufficient period of time to make it certain that the results truly represent average conditions. Operating and load conditions frequently vary so widely and quickly that with a large installation days or even weeks are required to obtain thoroughly dependable results. In such instances it is obvious that readings or data representing only a few hours of operation may be worse than useless.

To conduct a thoroughgoing survey of an industrial plant's power-generating and power-utilizing equipment, and obtain results that give a true picture of the conditions, requires skill and experience. These are required in added measure to interpret correctly the data collected and out of them evolve recommendations that are practical and economically sound. In all cases, general policies and plans of the management must be well understood before there can be certainty that proposed changes will work out satisfactorily and profitably.

From the results of such a study certain facts and possibilities usually stand out prominently. For example, if the load curves for electric power demand and for process steam are reasonably parallel, and in the proper ratio, an experienced engineer will at once recognize the possibility of making cheap, byproduct power, and therefore analyze this feature in detail.

Again, if bituminous coal is used at a high price per million B.t.u., and No. 3 buckwheat anthracite is available at one-third lower cost, he will study the economics of installing modern chain grate stokers.

May Have to Add Equipment

If the boilers are required to operate at a high rating, and no spares are available, it will obviously pay to investigate the advisability of installing an economizer, which may release a spare boiler and save enough fuel to make a good investment.

When the power plant is non-condensing and there is a considerable waste of unused exhaust steam, superheaters may be the answer; at least they should be investigated. Other solutions to be explored include the use of more efficient steam power units, operated in combination with diesel units, or purchased power for off-heating periods. When ample cooling water is available a bleeder condensing turbine should be considered. Again, higher boiler pressure and back-pressure turbine units may be the solution.

Many other arrangements and combinations are possible in order to satisfy various conditions and requirements.

In other cases the data obtained may disclose an old plant in which

Data to Be Obtained Through an

Location .....
Kinds of products .....
Full rated capacity of production .....
Production hours and work periods .....

GENERATION

Fuel

1. Kind of fuel consumed, and grade of each: coal, oil, gas, waste fuels.
2. Proximate analysis and B.t.u. of fuels used.
3. Delivered cost per 2,000 lb.; per gal.; per 1,000 cu.ft.
4. Applications of each fuel: steam generation; metallurgical furnaces; others.
5. Quantity of each fuel, and actual cost per year and by months for typical periods of factory production.
6. Method of storage. How much available at plant.
7. Fuel and ash handling equipment. Describe.
8. Other fuels available: prices and qualities.

Steam

9. Pounds generated per day and year. Maximum per hour demand. Report for same periods as in Item 5. Draw daily and monthly chart of steam production.
10. Actual evaporation per unit of fuel, per month, and per year.
11. Actual monthly efficiency of boilers and furnaces.
12. Fuel cost per 1,000 lb. of steam, actual.
13. Percentage of CO_2 at boiler uptakes and temperature of escaping gases.
14. Pressure and temperature of steam generated.
15. Temperature of feed water to boilers or economizer, and from economizer.
16. Anticipated changes in steam requirements.
17. Any chance to sell or buy steam?

Boiler Plant

18. Number and location of boiler plants on property.
19. Number of boilers.
20. Capacity of each boiler—water heating surface, sq.ft.
21. Type and make.
22. Age, condition, maximum working pressure allowed.
23. Height of setting.
24. State whether equipped with economizers, air preheaters, mechanical soot blowers.
25. Is draft forced, induced, or natural? Give type of chimney, diameter, and height.
26. Combustion equipment: hand-fired, stokers, oil burners, pulverized coal, gas. State make, type, capacity, and age of combustion equipment.
27. Combustion control equipment—automatic; make, type.
28. Boiler house auxiliaries: feed pumps, fans, blowers. How are they driven? How is exhaust from auxiliaries used?
29. Feed water heater, type and capacity. Percentage make-up water to boilers: summer, winter.
30. Raw make-up water, source and cost. Describe treatment and troubles. Give quantity, if possible.
31. Head room and floor space in boiler house. Available space for new units. Available space adjacent to boiler house.
32. What daily records of operation are maintained? What instruments used for securing these?
33. Boiler house force and payroll.
34. Maintenance, repairs and supplies for the above typical period (Item 5).

Electrical Energy

35. Total kw.-hr. generated in typical year (same period as Item 5).
36. Total kw.-hr. purchased in typical year (same period as Item 5). Total cost.
37. Secure or prepare load curves of generated and purchased energy, continuous daily, monthly.
38. Secure copy of contract under which electricity is purchased, with sample bills and alternate schedules.
39. Describe briefly electrical system, a.c. and d.c. Number and rating of transformers.
40. Load factor and power factor maintained for both generated and purchased power.
41. Power factor corrective equipment: number and rating of capacitors and synchronous motors or condensers.
42. Anticipated changes in electrical requirements.
43. Opportunities for selling or exchange of power.

Prepared by **DAVID MOFFAT MYERS,**

Industrial Plant Power Survey

Power Generating Units

44. Describe each power unit with its generator, including type, capacity, make, age, condition, water rate, initial and back pressures carried.

45. Engine room auxiliaries. List and describe.

46. Give same information for prime movers with mechanical drive.

47. Report kw.-hr. generated by each main unit in period covered by Item 5.

48. Schedule of hours of operation and output of each unit.

49. Condensers: type, vacuum carried, and units served.

50. Disposition of exhaust steam from each unit: process, heating, to condenser, to atmosphere.

51. Circulating water: source, temperature, how cooled.

52. Is warm circulating water used for process?

53. Steam driven air compressors: pressure, capacity, type, make, age, condition, hours of operation.

54. Maximum steam pressure and temperature permissible on each unit.

55. Give number, make, rating, age, condition of all diesel, water power, and gas engine units.

56. Space available for additional units in present building.

57. Power house force and payroll.

58. Cost of maintenance, repairs, and supplies for chosen period (Item 5).

APPLICATIONS

Power

59. List all motors and the machines driven. Give type, size, voltage, speed, make, condition, and actual test of load on each motor.

60. Electric lighting. Give number of lamps, type, volts, watts, rating.

61. Chart energy demand curve and schedule of use for all electric furnaces, ovens, and heating devices.

62. Is plant motored for individual machine, or lineshaft drive? Describe drives.

63. Give type and rating of largest motor drives that operate continuously during working day.

64. Are various manufacturing departments separately metered for electric consumption? Give data.

Heating

65. Amount of steam for building warming, by months. Pressure used. Is it live or exhaust steam? Maximum hourly demand. Distance of farthest point from power plant. Heating system employed: direct, indirect, unit heaters, vacuum-return, zoning, gravity return system.

66. Amount of steam for process, by months. Maximum amount per hour. Temperatures required. Steam pressures employed. Could these be lowered? Is live or exhaust steam used? Hours usage per day and per week. State nature of processes, describing briefly as possible.

67. Hot water requirements, gallons per month. Maximum hourly demand. Is live or exhaust steam used? Pressures. Are heat exchangers used to reclaim heat from discharged dirty water? Could water be heated and stored at night?

68. State quantity of clean hot drips wasted or returned to boilers or to other uses.

69. Quantity of exhaust steam wasted to atmosphere at what periods.

70. Is live or exhaust steam metered to departments or processes? Secure these records.

71. State kind, quantity, and cost of fuels burned directly for processes, heating buildings, ovens, or dry rooms, and in metallurgical furnaces. Give temperature of exit gas for consideration of waste heat boilers.

72 Indicate nature of heating difficulties or deficiencies.

73. Plot continuous chart of all steam uses, noting pressure of each.

COSTS and SAVINGS

74. Net cost of removing and disposing of any old equipment to be discarded.

75. Cost of new buildings, or changes in present buildings, excavations, foundations.

76. Secure manufacturers' prices on all new steam, power, and electrical equipment for each plan studied.

77. Cost of installation of all new equipment.

78. Cost of electrical wiring, transformers, switchboard, and other electrical connections and incidentals including proper complement of instruments, installed.

79. Cost of all steam, exhaust, water, air, and gas piping and insulation installed.

80. Cost of all breeching, flues, uptakes, ducts, and chimney if needed, all installed.

81. Cost of all recording, integrating, and indicating instruments needed.

82. Allowance for engineering costs and contingencies.

83. For each plan offering large savings make thorough engineering cost analysis. Develop total capital expenditure for each, with annual savings in operation, fuel, maintenance, and labor. Tabulate for comparison.

Consulting Engineer, New York

there is small demand for process steam. This situation automatically suggests the possibility of shutting down the old power plant, buying all of the electrical energy needed, and installing new low-pressure boilers or operating the old ones to supply steam for building heating, and process.

Analyze Alternative Plans

When all of the facts about a power installation are available it is frequently possible, sometimes necessary, to work out in detail a number of alternative plans for careful consideration of the merits and disadvantages of each. In the following example, which shows how this can be done, four plans were set up and analyzed.

		Annual Saving Production Year	
Plan	Investment	19-	19-
1	$135,000	$75,975	$65,969
2	13,500	5,270	5,090
3	15,850	9,394	6,736
4	270,000	7,000	6,360

Plan 1—Generate all electrical energy, both alternating and direct current. Install generating equipment as recommended in report. No change in mill engines.

Plan 2—Improve generation of d.c. energy only, and buy the remainder of the requirements, as at present. No change in the mill engines.

Plan 3—Buy all electrical energy requirements. Install motor-generator set for d.c. load. Purchase transformers. Make incidental changes necessary in electrical equipment.

Plan 4—Generate all alternating and direct current as in Plan 1. Electrify the mills and install additional required generating capacity.

The total steam and power demands and their relation to each other greatly affect the economy to be secured, particularly where exhaust steam, or the utilization of exhaust, is a factor. All of these values vary with the kind and volume of factory production. Therefore it is advisable when a fair average production year cannot be selected, to analyze and determine separately the savings for two or more past years. Minimum, maximum, and median results can be determined in this way. If future expansion is contemplated, estimates of costs and savings under the new conditions should also be included.

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L. O. VESER

Factory Management and Maintenance *Plant Operation Library*

How to Set Up a Program for
MOTION ECONOMY

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Consulting Editor

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CHAPTER ONE

Why a Motion Economy Program?

TODAY'S profits will not come from lower materials costs. They will not come from lower labor costs. They will come from increased operating efficiency.

Too many manufacturers, suffering from low production schedules, feel that the answer to all their troubles lies simply and entirely in increased activity.

"When we get back to the days of mass production," they sigh, "we'll be all set."

Maybe they will. Maybe they won't. Some manufacturers have already had substantial increases in production—only to discover that they did not automatically get lower costs.

Why not? For the obvious reason that lower costs will not come by themselves. Where a plant is tuned to economical manufacture at low production levels, sudden increases usually involve so many unforeseen factors that the higher costs entailed more than offset the savings due to the greater volume.

Not only are many concerns facing higher manufacturing costs. They are also discovering that their customers demand higher standards of quality than ever before. People are buying more critically. Every article is examined to make sure that the greatest value for the money is being received. Yesterday's quality standards will not do.

Today's Objective

Without question, then, the objective of every plant today must be *a better product at a lower cost—and at the right time.*

Is a motion economy program the answer?

Not the only answer. A motion economy program cannot attain the objective all by itself. But years ago Frank B. Gilbreth said:

"There is no waste of any kind in the world that equals the waste from needless, ill-directed, and ineffective motions, and the resulting unnecessary fatigue. Because this is true, there is no industrial opportunity that offers a richer return than the transformation of ill-directed and ineffective motion into efficient activity."

Another well-known industrial engineer said recently:

"At least 30 per cent of the average industrial worker's motions are waste motions."

This may sound high, but actual experience in plants where motion economy programs have been conducted, proves it no exaggeration.

It must be emphasized at the outset, however, that a motion economy program is *not* limited to motion study alone. In fact it subjects every function of management to a searching inquiry in order to find *the one best way.* It recognizes the fact that waste of time, waste of energy, and waste of material are often responsible for the difference between loss and profit.

A motion economy program, in short, sets out to discover practical methods of eliminating these wastes. In doing so, it is likely to check al-

most every phase of industrial management—factory organization, production planning and control, control of raw materials and purchased parts, inventory control and stores keeping, methods study and standardization, rate setting, incentives, layout, machine and equipment utilization, materials handling, cost accounting and analysis, safety, machine and tool design, product design, package design, operator training, and the thousand and one other items that go to make up the daily job of managing an industrial plant.

Perhaps the term, a motion economy program, is not the best way to describe this activity. Perhaps it might better be called a course in industrial management. One thing is certain. Whatever the skeleton around which the structure is built —whether it is called cost reduction, waste elimination, methods study, motion economy, or what you will—it sets out to enlist the active cooperation of every individual in the enterprise in attaining the objective—*a better product at a lower cost, and at the right time.*

CHAPTER TWO

A Job for Everyone in the Plant

HOW MAY the objective be reached? In one of two ways. The first is to bring in the "expert," have him study the methods, and make recommendations. Most people recognize the advantage of having someone with an outside viewpoint study existing practice. It is usually difficult for the man close to the job to stand off far enough to realize that perhaps there are better ways to do it. And too often experience brings with the years a closed mind.

Despite the advantages of the outside viewpoint, coupled with specialized training and experience gained from similar work in other plants, the outsider must be prepared to meet a tremendous amount of antagonism.

This antagonism may be traced to perfectly natural human traits. We resent criticism and resist every new idea. No matter how open-minded we may try to be, we must face the fact that a new idea must overcome a great deal of natural resistance before we are willing to give it fair consideration.

Easy to Look Back and Smile

If you doubt this, just check your own attitude toward some of the recent developments. I mean such things as balloon tires, ethyl gasoline, streamlining, knee action—and now diesel engines as applied to the automobile; the airplane, of course, air-conditioning, modern housing, and so on. Remember it is always easy to look back and smile at our own defections along this line, but few of us can look ahead and predict our reactions to new things.

However, there is a much more serious obstacle to the acceptance of new ideas, especially when suggested by an outsider. It is our resentment of criticism. Dr. Harry Myers once said:

"The people who help me most are those who tell me where I am wrong."

Why Outsiders Often Fail

But how many of us really welcome criticism? How many of us can take a suggestion for improving some procedure of ours without bristling a bit and telling why we are justified in doing it our way? Seldom have I gone through a plant and offered some little suggestion that might improve a method without being immediately told all the reasons why it must be done that way. How many times have you visited someone's plant or department and noticed something you thought might be improved? Have you not usually been told that their business is different and an outsider naturally would not understand all the reasons why they must do it that way?

To my mind, then, this is the reason why the expert from the outside, no matter how good he may be, often gets nowhere with the average department head or foreman.

Which brings us round to the second method of obtaining our objective. This method is to enlist the cooperation of every single member of our organization. If, instead of one methods man, we have several hundred, our chances of getting results are just that much better.

Sounds good, but can it be done?

Yes, if a proper training program is set up and followed. There is only one way to get the whole organization in on the job of making a better product at a lower cost and at the right time. *That is through the foreman.*

I am not the only one who feels that way. In fact, I find myself in the best of company. For example, William S. Knudsen, executive vice-president of General Motors, said recently:

"The industrial science I look forward to will be the relationship that we establish on the basis of cooperation between the men and the foremen. Here is our problem, and it should be our problem for years to come. The biggest thing before industry is to get better management out of all departments, and through cooperative methods give more and better work so that the public's interest in our product can be retained and our future assured."

Is the average foreman smart enough to do this job?

Yes, he is. Darwin once said "there are more men with adequate brains than we think, but they lack that quality of enthusiasm that is hard to define." It is not so much a question of the foreman's ability or intelligence as it is of securing his enthusiastic cooperation by convincing him that this is an essential part of his job of supervision. A motion economy program need not be something separate and apart, but will in itself make the foreman a better manager of his department.

Saved $464,284

In one plant where about 150 men took part in a training program, 1,200 suggestions were received in a period of 20 months, with an estimated savings of $464,284. Of them, 677 have already been put into effect; only 396 have been definitely rejected. In another plant where only 110 men participated, 794 suggestions were received in the same period. Of these, 404 have been adopted and put into effect, and only 181 finally rejected.

These are not unusual examples. On the contrary, they are typical of results secured under many other properly conducted programs. Proportionate results have been secured in small plants, and regardless of the nature of the industry.

But is this not a job for the methods engineer?

A training program in motion economy for foremen and supervisors will not in any way replace or sup-

plant the methods engineer or the time-study man. It will, however, make their work much easier and many times more effective. First of all, instead of having to scratch around for possibilities, they will find their hands full investigating suggestions made by foremen and operators. Instead of being that "blankety-blank efficiency man" or that "so-and-so with the stopwatch," they will find themselves regarded as consultants.

They'll Be Asking for Help

Foremen who perhaps have resisted every attempt for methods improvement will be asking the methods man or the time-study man to come and help him get the answer to a specific problem.

How complete this about-face may be, is well illustrated in this quotation from a letter written by just such a department head:

"I've had my sights raised considerably by the time- and motion-study work that has been done in my department in the last few months. I have learned that workers, apparently very busy, can be wasting a lot of time through unnecessary and awkward motions. I have also discovered that a great deal of labor cost can be saved by accumulating the little fractional savings from many jobs and then reorganizing the entire work so that each man has his time effectively occupied.

Wages of Waste

"I had always thought of time study as a method of speeding men up. Now I realize that the scientific studying of motions on a man's job can greatly increase his output without increasing the amount of energy he has to expend. Our time-study work has done a great deal to eliminate the motions and operations that tire out a worker needlessly. It has proved to us that needless lifting, moving, walking, reaching, and bending not only make work more tiring for workers but also make work much more expensive because a needless motion takes time and costs wages just the same as a useful motion.

"By explaining to our workers that the purpose of time study was not to crowd them but to make their work easier and to improve their earnings, we overcame any antagonism that I quite naturally expected to see develop."

(Reference: April, 1935, p. 147.)

CHAPTER THREE

Equipping the Foreman

OBVIOUSLY, few foremen can or will equip themselves to do a thorough job of improving existing methods. They require help—first, in learning what the tools are and how to use them; second, in learning how to pass this information on to their men.

Most managers expect their foremen to be able to do this training job without ever stopping to consider whether or not they are qualified to do it. Thorough knowledge of the job and ability to perform it does not in itself insure ability to teach it to others. Teaching is in itself a profession. Each foreman must therefore be taught how to teach.

But what does all this cost?

Such a training program is not an expense. If conducted properly, it will pay for itself many times over. One does not even have to wait until the completion of the course to measure results. Improvements in quality, lower costs, and reductions in manufacturing interval can all be traced to suggestions made by foremen as they start to use the tools provided.

What method should be followed in conducting such a program?

The training is best accomplished by holding a definite series of meetings for the foremen.

Should meetings be lectures, conferences, or discussions?

The lecture method alone is likely to fall short of success. No matter how interesting the subject, one always tires of merely sitting and listening to someone else tell how it should be done. The first few meetings, at which the tools are described, must perforce be pretty much lectures, but as soon as the men begin to try out the tools, the meetings can be swung over into the conference type of program. Discussion should be invited. Individual problems should be considered as far as time permits.

Plenty of Things to Discuss

When definite assignments are made, the instructor will have no lack of material for discussion at subsequent meetings. He must, however, cover a definite topic at each meeting and not allow too much detailed discussion to prevent completion of the planned work. Care must be taken to see that the subjects of the discussion are representative of problems being met by all in the group.

Who should conduct the meetings?

Some plants have had courses conducted by men trained in teaching, such as instructors in university extension courses. Others have had programs conducted by consultants specializing in this work. Still others have selected some man from their own personnel and had him supervise the program.

Pick Your Man; Back Him Up

In the metropolitan area some concerns have sent one or two men to take an intensive training course in motion study at New York University, and they in turn have conducted the program for foremen and supervisors at their plants. Several plants have had successful programs led by one or two men in the organization who became interested in the subject, studied it, and then embarked on what might be termed a joint venture in motion-economy training. If a plant can find a man in the organization who is really interested in doing the job, and will back him up with complete cooperation, the results will more than repay the effort that has been made.

Should the meetings be confined to foremen, or should executives sit in?

Obviously, many foremen will not open up if executives sit in. On the other hand, I have seen several successful programs where the president of the company and other major executives took as active a part in the discussion as the foremen, and there was no hesitancy at all in discussing any and all problems. Certainly, there is much to be gained by having every foreman realize that top management is not only interested, but also takes an active part in the program.

In any event, the executives cannot be left out of the program. If they do not sit in with the foremen, a special group should be formed to discuss the progress of the work and to keep the executives informed so that they will be able to see the supervisor's viewpoint.

Some programs fail because the foremen and supervisors are given intensive training in the application

Figure 1. Best way to get the whole organization in on the job of making a better product at a lower cost is through the foremen. Here, a group at Olds Motor Works, Lansing

of good management principles, are told that the proper procedure is to get the facts first before making a decision, and then find some of the executives demonstrating their ability to run the business on hunches. The executives and top management must, after such a period of training, keep just as far in front of the foremen group as they were before the program was started.

The make-up of the group will necessarily vary with the plant. Where it is not practicable to pull out all the supervision from a certain department at one time, it may be well to have groups made up of men from various departments. The most effective results, though, are secured by having a group with a unity of interest.

Should meetings be held on company time or on the man's time?

Successful programs have been conducted under both methods. Meetings after hours should indicate interest on the part of those attending. Unfortunately, it doesn't always, because some foremen are afraid that if they do not attend it may be held against them.

Things We Pay For

Meetings held during hours, on the other hand, are apt to be interrupted by frequent phone calls, which necessitate one or more of the men leaving. Interruptions of this sort are not at all conducive to effective attention.

If it is possible to do so, then, and if the men come voluntarily, meetings after hours are preferable. We always place a higher value on something we pay for, and even though the men are not asked to pay for the program out of pocket, they nevertheless feel that when they give their own time they are contributing something, and expect to get something in return.

Motion economy programs offered by university extension groups have been known to attract large and enthusiastic attendance from men who paid their own tuition. If, however, the management expects to benefit from such a program, it is not unreasonable to expect that all out-of-pocket expenses should be borne by the company.

How often should meetings be held?

Every two weeks to be most effective. One a week does not give enough time to complete the assigned work. One a month allows the interest to flag.

How large should the group be?

Too large a group will be unwieldy and disappointing as to results. If possible, the group should not number over 25. If more than 25 are to take the course, several groups should be made up.

One mistake frequently made is to include too few men. Management often forgets that the assistant foreman of today may be the foreman of tomorrow. Wherever possible, the men who look like good foreman material should be included.

What aids should be used?

First, an outline of the material covered during each meeting should be given to each man as soon as possible after the meeting. Few foremen know how to take good notes, and it is therefore essential to put the material in such shape that they can go over it between meetings.

Notes need not be elaborate, but should hit the high spots. Wherever possible, notes should be interspersed with questions designed to stimulate the thinking beyond the points covered during the session. Some of the plants conducting motion economy programs have given each member of the class a copy of one of the available texts. This practice, however, is to be questioned, because few can resist the urge to read ahead. This often distracts the attention and confuses the man, whereas if he were given the same material, one chapter at a time, he would have to work out each of the various steps before going on to the next.

Pictures Help Tell the Story

When process charts are being made, one or two should be drawn up large enough for the whole group to see. Other charts and posters are effective in getting across certain steps and methods. Never forget the Chinese proverb: *"One picture is worth 10,000 words."*

Motion pictures are most effective aids. Although they may seem expensive, there is nothing like "before and after" motion pictures to stimulate interest. Films need not be elaborate; the simpler the illustration, the better. Films showing operations other than those with which the group are directly concerned are especially effective at the start. Later on these illustrations can swing over into operations that have been brought out as case illustrations by the group.

Elaborate equipment is not necessary in order to make these films; in fact, there is hardly a plant today where someone does not already have amateur motion-picture equipment. The 8-mm. equipment is inexpensive and requires little more than the hand-held camera, but is not as effective as 16-mm. pictures for showings to large groups. Where the factory lighting is not sufficient, a few inexpensive photo-flood bulbs will furnish enough illumination. If no one in the plant can make these films, your local dealer will no doubt be glad to assist.

(References: Sept., 1932, p. 337; March, 1933, p. 111; July, 1933, p. 265; Dec., 1933, p. 482; Aug., 1934, p. 347; May, 1935, p. 195.)

CHAPTER FOUR

Five Tools of Motion Economy

PROGRESS in any line of work depends a good deal upon the accuracy of the measuring tools used. Precision machines or products would be impossible were it not for accurate measuring tools that have made their production practical. The same is true with good management. There is no question that the manager of today who has all the facts is in a better position to make competent decisions than when working entirely by rule of thumb.

In order to eliminate waste—waste of time, energy and materials—we must:

1. Recognize the problems:
2. Discuss these problems with those concerned;
3. Outline possible solutions;
4. Assign the various problems to those fitted to handle them.

Our measuring tools fall into the following five classes:

1. Process chart;
2. Clock;
3. Stopwatch;
4. Motion study;
5. Micromotion study.

It should be evident that none of these tools is universally applicable. If we make a micromotion study where only a process chart or stopwatch study is justified, the result will be *waste*, which is the very thing we are trying to eliminate. Likewise, if we make a study only with the stopwatch, when we should analyze every part of the operation by means of micromotion study, we are not exploring every possibility —and again we have *waste*.

Which Tool Is Best?

Any attempt to argue the general use of one method of measurement as against another is just as ridiculous as attempting to stage an argument between a carpenter and an expert toolmaker. Suppose we had the carpenter before us with his wooden rule and the toolmaker with his vernier micrometer, and said:

"Now I want each of you to tell why your own tools are best suited for making this wooden flower box."

Naturally, they would reply that there was no argument at all—that the wooden rule was all that was necessary for the accuracy required to build such a simple thing. On the other hand, if we were to build an accurate die or jig, we should expect the toolmaker to use his precision measuring instruments, so that we might secure a piece of equipment that would function properly.

The workman uses the caliper and scale for rough dimensions only. He does not expect to read to thousandths of an inch unless he uses the proper measuring tool—the micrometer. Even in the days of strictest economy, no one would think of pawning all the micrometers and asking the toolmaker to get along with a steel scale.

If management does not use the proper measuring tools, will its "guess" measurements be less expensive than the "guess" measurements of the workman would be? Must we not apply the same common sense in the use of management's measuring tools as we expect the workman to do in the use of his?

Three Tools for the Foreman

Not all these tools will be used by the same individual. The process chart, the clock, and motion study are all tools that we should expect the foreman of today to be able to use effectively. When he wants to use the stopwatch, he may find it necessary to call in a specialist—the time-study man—to assist him in its use. The fifth and last tool—micromotion study—is distinctly a tool for the specialist, and is introduced here only because the foreman should know what it is and what it can do for him.

CHAPTER FIVE

How to Make a Process Chart

ONE of the most valuable tools of measurement is the process chart. It is a detailed record indicating the sequence of any process. It is a device for visualizing a process as a means of improving it. First developed by Frank Gilbreth, it was applied by him in many different lines of work. He tells the story of the time he took a process chart to show a plant executive. When the chart, which stretched clear across the room, was unrolled for inspection, the executive said:

"See here, Gilbreth, I don't even need to look at this to know that I'm absolutely against it."

"But," said Gilbreth, 'this is not a process chart of any proposed method. It is only an exact representation of the process as it now exists in your plant."

The process chart serves as an indicator of profitable changes. It acts in many instances like the pawl of a ratchet wheel, permitting forward progress by preventing the retracing of steps already taken. It is not only, as Gilbreth said, *the first step in visualizing the one best way to do work,* but is also useful in every phase of deriving it, even if existing conditions are apparently satisfactory from every angle.

Facts in a Nutshell

Process charts are of special value in presenting information in condensed form. Many a manager has found himself irritated, even baffled by his inability to visualize the whole process under his direction. He must therefore make decisions based on incomplete knowledge, which are often little better than guesses and may prove disastrous.

The use of the process chart reverses the usual procedure in a job study. Instead of making a change in any subdivision of a process,

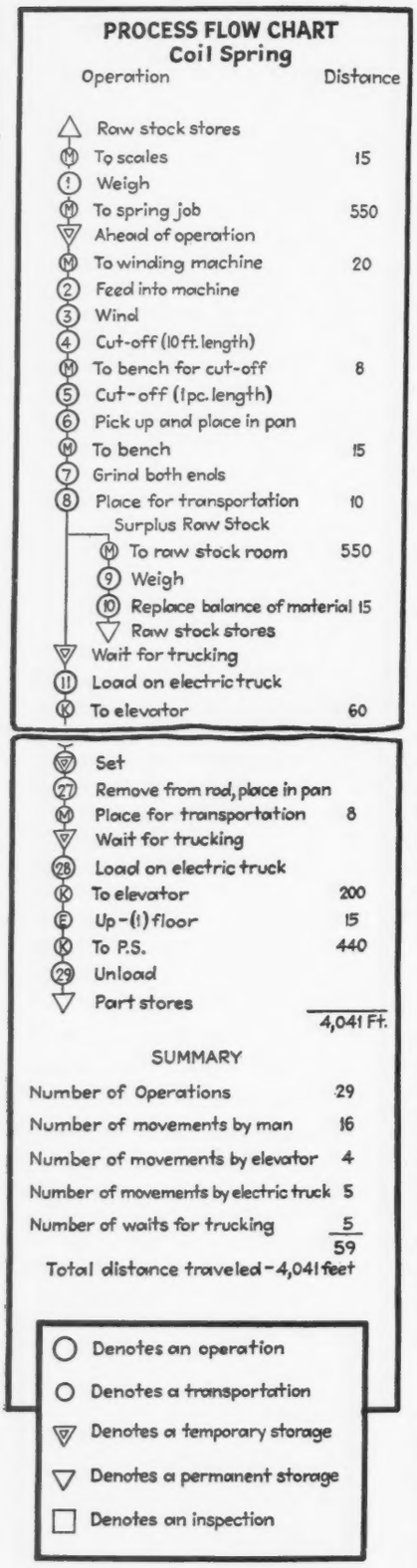


Figure 2. Process chart is No. 1 tool of motion economy. This one shows 59 steps, with 4,041 feet of travel—all to make a tiny coil spring

merely because that particular one may be the easiest to change, or may appear to be the one offering the greatest opportunities for improvement, it permits consideration of all those subdivisions preceding and following the one under consideration. Unless they are considered, the change may be found to be unsuited to the ultimate plan of operation.

Process charts are of three general types—the flow process chart, the man and machine chart, and the right- and left-hand chart.

Every Move from A to Z

The flow process chart is made by following materials, men, or paper records through the entire process. It shows the route of the object from the beginning of the process to the end, keeping that one object in mind. Wherever a move occurs, the distance traveled is shown. Total distance is summarized at the bottom of the chart.

A chart of an operator in the performance of his duties often shows a tremendous amount of travel. It is usually effective to chart a part and a man on the same sheet. Such a chart would have two columns—one showing distance traveled by the part or material, the other by the operator. Charting in this manner may save making two separate charts, and emphasizes the fact that the man often returns empty-handed.

For Paperwork Also

A great many concerns today are giving special attention to the study of paperwork. Elaborate systems are often built up to handle procedure that may have been satisfactory several years ago, but may now be only an expense. Here again the flow process chart is a useful tool. It can be drawn for a paper form or record and indicate all the steps followed as this form multiplies in numbers of copies and progresses through the various steps to its final resting place in the files.

How is the chart drawn?

First of all, five simple symbols are used to cover any job to be analyzed. They are illustrated in Figure 2. The large circle denotes an operation. This may be "pick up sheet," "unload from truck," "grind outside surface," "type information on order blank," or any other real operation performed.

A small circle denotes a transportation. This may be amplified by small letters or symbols placed within the circle to indicate whether it is by operator, truck, elevator, conveyor, etc.

The third symbol—a double triangle—indicates a temporary storage, while the fourth — a single triangle — indicates a permanent storage. It is difficult to define the point where a storage leaves off being temporary and becomes permanent. However, it is the usual custom to start and stop the chart with a permanent storage (if it is stored) and have most of the storage steps between those two points appear as temporary storages. This would not be true if a part goes into a stockroom, let us say, in quantities of 5,000 pieces, and then is drawn upon from time to time in small lots. In that event it is a permanent storage. One practice is to consider it a permanent storage whenever paperwork, such as a requisition or an order, is required to remove material from the storage.

For an Inspection, a Square

The last symbol—the square—denotes an inspection. This may be an inspection for quality, such as gaging or visual inspection, or it may be an inspection for quantity, such as counting or weighing.

A great many additional symbols and combinations of symbols are possible. However, they can become too complicated, and it is certainly advisable to stick to the five at the start. It is customary to number only operations and inspections. The use of these symbols is well illustrated in Figure 2.

Process charts are easy to make. However, a process chart cannot be drawn sitting at a desk. Reference to Figure 2 will show the detail that must be set down if the chart is to be of any value. One must actually follow the part or operator through all the steps. The mere act of investigating sufficiently to make the notes valuable enough for someone else to study or discuss, invariably results in suggestions for improvement. All suggestions, good and bad, should be retained and filed with the process chart, and held for discussion.

Who Gets the Best Results?

The person who makes the chart need not be familiar with all the details of the process. In fact, an intelligent, unbiased, and experienced process-chart maker usually gets better results than one with

more special information regarding present practices, but who is not quite so keen an observer.

Make the first assignment a process chart of some everyday habit or procedure. The one selected should be something that is not consciously done—a process chart on getting dressed in the morning, for example, or getting out the car and driving to the plant, or getting out the garden tools for an afternoon's work, or going down to fire the furnace. These are all simple operations, done day after day by many of us, but when drawn up in proper chart form, listing distance traveled, as well as number of operations, transportations, and so on, will demonstrate the value of making a process chart on some regular shop operation with which the foreman may at the present time feel entirely familiar, but whose actual details he does not even comprehend.

After one or two simple practice charts have been made, have each member make a flow process chart of some product. Have them use the symbols shown in Figure 2 and list the distance traveled. It is best to stay away from flow charts of paper records at the beginning, as they often become too complicated and may discourage the learner.

Charts should be turned in, and the instructor should correct them. He should not attempt to get into the details of the operation, but should merely make certain that each chart is made properly, and that each man thoroughly understands how to use the symbols.

(References: June, 1933, p. 214; July, 1934, p. 298; Dec., 1934, p. 538; Jan., 1935, p. 16; Aug., 1935, p. 350.)

CHAPTER SIX

How to Analyze the Chart

AFTER the process chart has been drawn, common sense is all that is necessary to increase the efficiency or better the process. The needless, ill-directed, and ineffective moves and operations are readily seen. Someone with little or no experience in methods study can check through the operations and suggest improvements.

The chart makes possible a discussion by everyone interested, because it records and visualizes exactly what is going on and presents specific topics for consideration. Study of the chart suggests operations that may be eliminated, and combinations or simplifications that may readily be made. It saves considerable detailed study of operations that should be eliminated before such studies are made. It makes possible a graphic plan of procedure and permits allocations of time to be spent in detailed study through the various parts of the whole problem.

The process chart clearly shows the three divisions of any job—the MAKE READY, the DO, and the PUT AWAY. It is usually true that more time is spent on the MAKE READY and PUT AWAY than on the actual DO part of any job. Too much attention has been spent in studying the DO in past years.

Thus, instead of trying to speed up some individual operation, attention must rather be focused on other phases of the operation where opportunities for improvement are not so obvious. These opportunities are often uncovered by soliciting suggestions from those working directly on the job. It is too often assumed that the operator is incapable of making such suggestions. Actually, some of the best come from this source.

As a result, a whole process may be changed. A forging may be substituted for cut-off stock; grinding suggested instead of a screw machine operation; milling replaced by broaching. Or methods may be adapted from an entirely different industry, such as the application of the continuous circular heat-treating furnace to the porcelain-enameling industry.

The greatest value from the process chart will come out of group discussions. A good leader, questioning an interested group, will soon have enough notes on the chart to keep someone busy for quite a while getting the answers to the points raised. Kipling summed it all up in a nutshell when he wrote these lines:

"I keep six honest serving men,
They taught me all I know,
Their names are What and Why and When,
And How and Where and Who."

Those are the questions the process chart helps answer — WHY? WHAT? HOW? WHO? WHERE? WHEN?

1. *Why* should the work be done?
2. *What* is to be done?
3. *How* is the work to be done?
4. *Who* is to do the work?
5. *Where* is the work to be done?
6. *When* is the work to be done?

This questioning attitude develops the point of view that considers the good of the plant rather than of a department or an individual. It brings out the best type of operator and equipment needed. It determines where the job can be most economically performed and evens out the flow of work. And by asking the first question at each step, it often develops that a part of the work, or sometimes the whole work, is unnecessary.

Procedure can be simplified, especially at the beginning, by subjecting every single symbol on the chart to these four questions:

1. *Can the operation be eliminated?* If not, and you are sure of it,

2. *Can it be combined with some other operation?* If it cannot, then

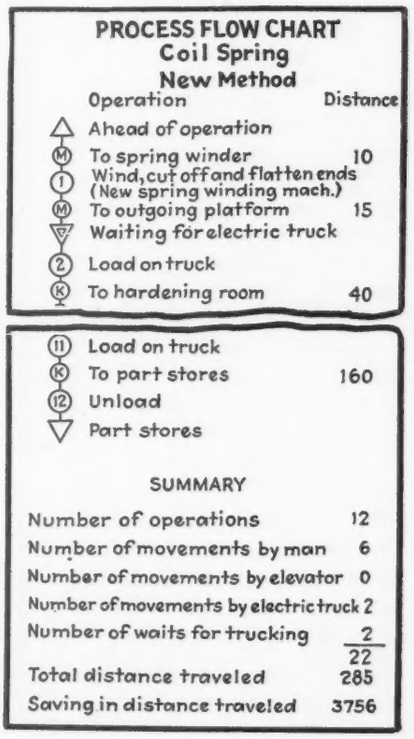


Figure 3. Same coil spring, but the 59 steps have now shrunk to 22. Total distance traveled, 285 feet. Annual savings, $3,600

3. *Can we change the sequence of operation?* If not, then and only then,

4. *Can it be simplified?*

One of the reasons why methods work has not been successful in all applications is because too many people start with the fourth item. As Dr. Lillian Gilbreth says: "There is altogether too much time spent in studying work that should never have been done."

A great deal of the success of the program depends on how well the work is handled at this stage. First of all, the instructor must remember that the foremen have a great many duties in addition to making up process charts. He must not be too insistent in assigning the work and expecting immediate results. Time must be allowed, considerable patience exercised. It is, therefore, a good plan to spread out the meetings at this stage and give plenty of time for discussion of the individual problems that may arise in the making and consideration of the chart. If possible, the instructor should visit each man on his job, and sit down and go over his chart with him.

Results Begin to Show

It is at this point that the actual worth of the program should begin to be apparent. As a result of some of the suggestions, the instructor should be able to report definite progress in cost reduction and see that each foreman or member of the group receives proper credit for his ideas. As Charles M. Schwab so aptly put it:

"I am a believer in the fact that men do their greatest accomplishments by proper encouragement—not by criticism. I have yet to see the man, however great and exalted his situation, who is not susceptible to the approval of his fellow men. I have yet failed to see the man, who is worth calling a man, who does not put forth his best efforts under the approval of his fellow men."

After the first process charts have been made and gone over, the instructor should ask each man this question:

"Did you learn anything in making this chart that you did not know before?"

If he did not, it would indicate that he is not yet sold on the value of making any more. It would therefore be a good plan to go over in detail with this man every detail of his chart.

It is worth while at this stage to have the men draw up a few simple flow diagrams that will help them visualize the actual travel made by the man or the product throughout the department or plant.

Figure 3 shows the final proposal for the process charted in Figure 2. This proposed method was the result of study and discussion on the part of a foremen's group, and was directly responsible for savings in travel and time amounting to $3,600 a year.

The group should not go on to the next tool until every member of the group has made a present-method flow chart, a proposed chart from the present one, and submitted some suggestions for improvement of the particular operation studied. Above all, the instructor should remember that a clear understanding of instructions is essential if work is to be done right. There are four steps that insure that clear understanding. They are:

1. TELL him how;
2. SHOW him how;
3. TEST him;
4. CHECK him, and supervise.

Close adherence to this procedure will insure maximum appreciation of the value of this first tool of motion economy.

(Reference: Jan., 1935, p. 16.)

CHAPTER SEVEN

Clock and Stopwatch

SO FAR our process charts have listed only the steps followed and distance traveled. *The next step is to add time to the chart.* We must consider the order of time just as much as the order of things if we are to eliminate waste.

In a process chart made of a paper form or record, time is of especial value. For example, when one has completed the flow process chart on the movement of a form, one might well put down the time required for the performance of each step in the operation. Likewise, the time required to transport the form from one operation to the next can be closely ascertained. Adding such a list of times might give a result of, say, three hours. Then a check of the average time required for the form to travel through this routine might well show it to be a matter of days, perhaps weeks. It then becomes a simple matter to question each one of the delays along the line.

The same thing can be done in the shop. A flow process chart with time added might show that under ideal conditions the part should be transformed from raw material to finished product in, let us say, two days. Under a particular rush condition, it has been done in one day. However, under normal conditions it averages two weeks. The question can then be raised: *Why can we not move every order through in one or two days?*

There may be a good reason why not, and obviously the answer is not as simple as it may seem. Nevertheless, it often can be done. No one will question that one of the biggest problems facing industry today is that of reducing manufacturing interval. Profits may be made by increasing turnover and reducing work in process that far outdistance cost reduction in the item of direct labor —where most of our efforts have been expended in the past.

Men and Machines

We are more interested in delays as they affect machines rather than mere loss of time on the part of the operator. For this purpose there is no tool like the "man and machine" process chart illustrated in Figure 4. It is made up of two columns, one headed "Operator," the other "Machine." It shows in chronological order the operations and moves performed by the operator, together with the time element and the distance traveled. It does not go into any of the subdivisions of the motions or operations. Under the "machine" heading are shown the starts, stops, machining operations, and idle machine time in relation to the movements of the operator.

In the average machine shop the operator will signal for the overhead crane, wait until it arrives, and then load his casting in the machine. Then he starts to hunt for clamps and clamping bolts. The latter may be under a bench or on another machine. All this time the machine is standing idle. The use, in one plant,

of a metal cabinet for all tools, gages, and drawings used in the assembly of a large piece of equipment resulted in the saving of 42 miles of walking and some 70 hours of waiting time. Containing all tools and drawings used, it eliminates the need for numerous trips to the toolroom, all wasteful of the operator's time in addition to keeping expensive machines and equipment idle. In another plant, all small tools and gages are made up in the toolroom in packet form for each job, again saving numerous trips to the crib.

There is no doubt that we are paying too much for walking and waiting time at present. When this is expressed in terms of footage traveled or is shown as idle machine time, improvements are not long in forthcoming. Of especial importance is the summary at the bottom of a man and machine chart. This summary shows total elapsed time, total distance traveled, machine time, personal time, waiting time, and handling time. Other classifications may be found of value in various types of work.

Needed a Calendar, Not a Clock

This time measurement is rough—one that may be made by any foreman. It is not stopwatch time study. In fact, as one foreman remarked, when his group was studying charts of this type: "What we need here is not a clock but a calendar."

Meetings devoted to this particular topic should emphasize the third phase of the main objective—*"and at the right time."* One thing that will be evident is that much of the lost time in industry today is not as much the operator's fault as it is management's.

Lack of planning is no doubt responsible for most of the time wasted in the shop. Poor instruction comes second. A great deal of waste motion and waste time lost by workers can be attributed to lack of proper instruction at the outset.

Poor equipment comes next in the list. The point here is not so much that machines or tools are inadequate or obsolete as it is mere failure to keep them in proper operating condition. A little time spent in any shop actually watching an operator at work will verify this.

Procrastination is the fourth time waster, and while it does not need a chart to bring this to light, it should be brought out in the discussion.

For exact measurements of time,

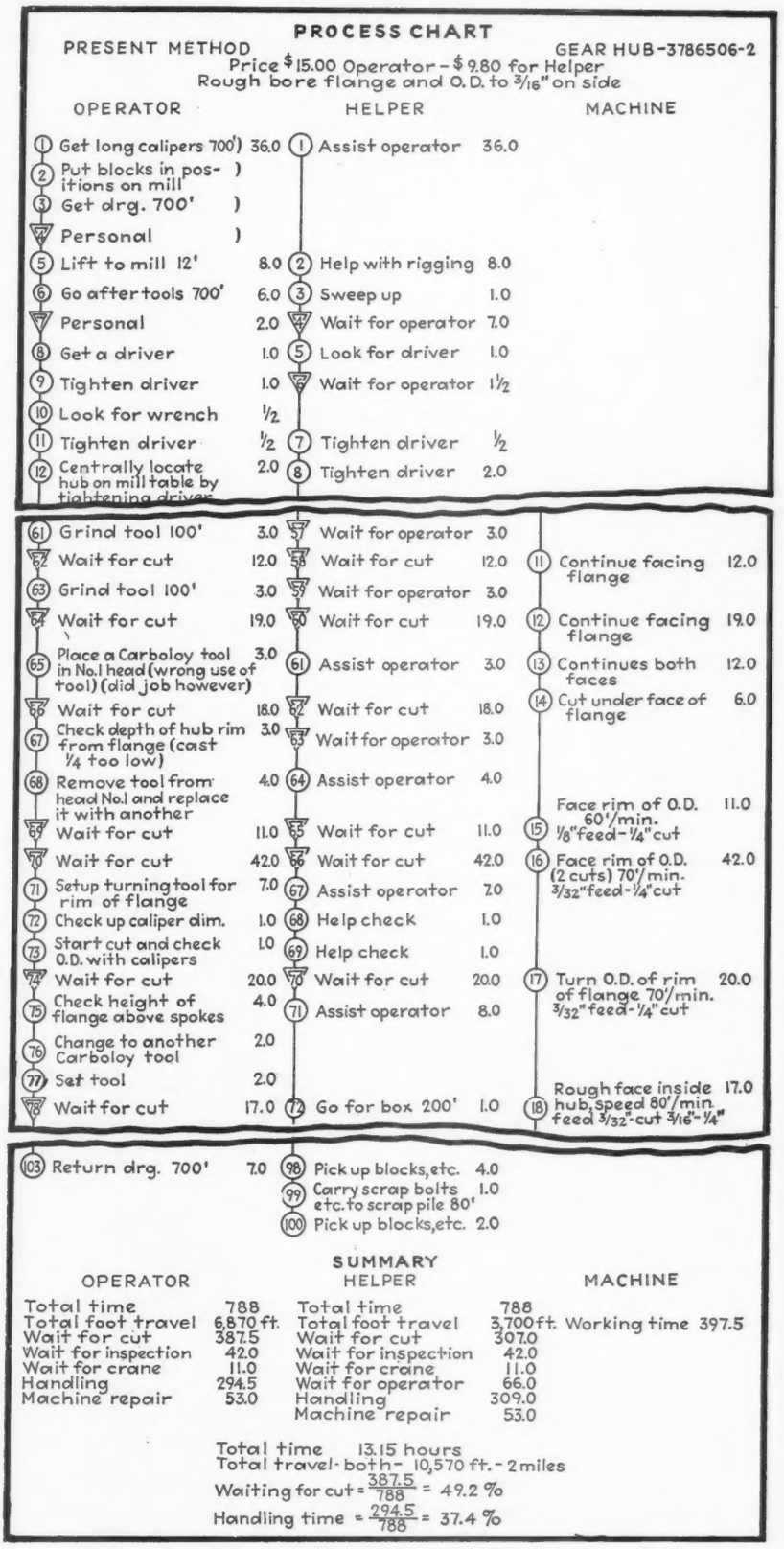

PROCESS CHART
PRESENT METHOD
GEAR HUB-3786506-2
Price $15.00 Operator - $9.80 for Helper
Rough bore flange and O.D. to 3/16" on side
OPERATOR
HELPER
MACHINE
1 Get long calipers 700' 36.0
2 Put blocks in positions on mill
3 Get drg. 700'
4 Personal
5 Lift to mill 12' 8.0
6 Go after tools 700' 6.0
7 Personal 2.0
8 Get a driver 1.0
9 Tighten driver 1.0
10 Look for wrench 1/2
11 Tighten driver 1/2
12 Centrally locate hub on mill table by tightening driver 2.0
1 Assist operator 36.0
2 Help with rigging 8.0
3 Sweep up 1.0
4 Wait for operator 7.0
5 Look for driver 1.0
6 Wait for operator 1 1/2
7 Tighten driver 1/2
8 Tighten driver 2.0
61 Grind tool 100' 3.0
62 Wait for cut 12.0
63 Grind tool 100' 3.0
64 Wait for cut 19.0
65 Place a Carboloy tool in No.1 head (wrong use of tool) (did job however) 3.0
66 Wait for cut 18.0
67 Check depth of hub rim from flange (cast 1/4 too low) 3.0
68 Remove tool from head No.1 and replace it with another 4.0
69 Wait for cut 11.0
70 Wait for cut 42.0
71 Setup turning tool for rim of flange 7.0
72 Check up caliper dim. 1.0
73 Start cut and check O.D. with calipers 1.0
74 Wait for cut 20.0
75 Check height of flange above spokes 4.0
76 Change to another Carboloy tool 2.0
77 Set tool 2.0
78 Wait for cut 17.0
57 Wait for operator 3.0
58 Wait for cut 12.0
59 Wait for operator 3.0
60 Wait for cut 19.0
61 Assist operator 3.0
62 Wait for cut 18.0
63 Wait for operator 3.0
64 Assist operator 4.0
65 Wait for cut 11.0
66 Wait for cut 42.0
67 Assist operator 7.0
68 Help check 1.0
69 Help check 1.0
70 Wait for cut 20.0
71 Assist operator 8.0
72 Go for box 200' 1.0
11 Continue facing flange 12.0
12 Continue facing flange 19.0
13 Continues both faces 12.0
14 Cut under face of flange 6.0
15 Face rim of O.D. 60'/min. 1/8" feed - 1/4" cut 11.0
16 Face rim of O.D. (2 cuts) 70'/min. 3/32" feed - 1/4" cut 42.0
17 Turn O.D. of rim of flange 70'/min. 3/32" feed - 1/4" cut 20.0
18 Rough face inside hub, speed 80'/min. feed 3/32" - cut 3/16" - 1/4" 17.0
103 Return drg. 700' 7.0
98 Pick up blocks, etc. 4.0
99 Carry scrap bolts etc. to scrap pile 80' 1.0
100 Pick up blocks, etc. 2.0
SUMMARY
OPERATOR
Total time 788
Total foot travel 6,870 ft.
Wait for cut 387.5
Wait for inspection 42.0
Wait for crane 11.0
Handling 294.5
Machine repair 53.0
HELPER
Total time 788
Total foot travel 3,700 ft.
Wait for cut 307.0
Wait for inspection 42.0
Wait for crane 11.0
Wait for operator 66.0
Handling 309.0
Machine repair 53.0
MACHINE
Working time 397.5
Total time 13.15 hours
Total travel - both - 10,570 ft. - 2 miles
Waiting for cut = 387.5/788 = 49.2 %
Handling time = 294.5/788 = 37.4 %

Figure 4. Man-and-machine process chart records starts, stops, machining operations, and idle machine time in relation to the movements of the operator and—in this case—his helper

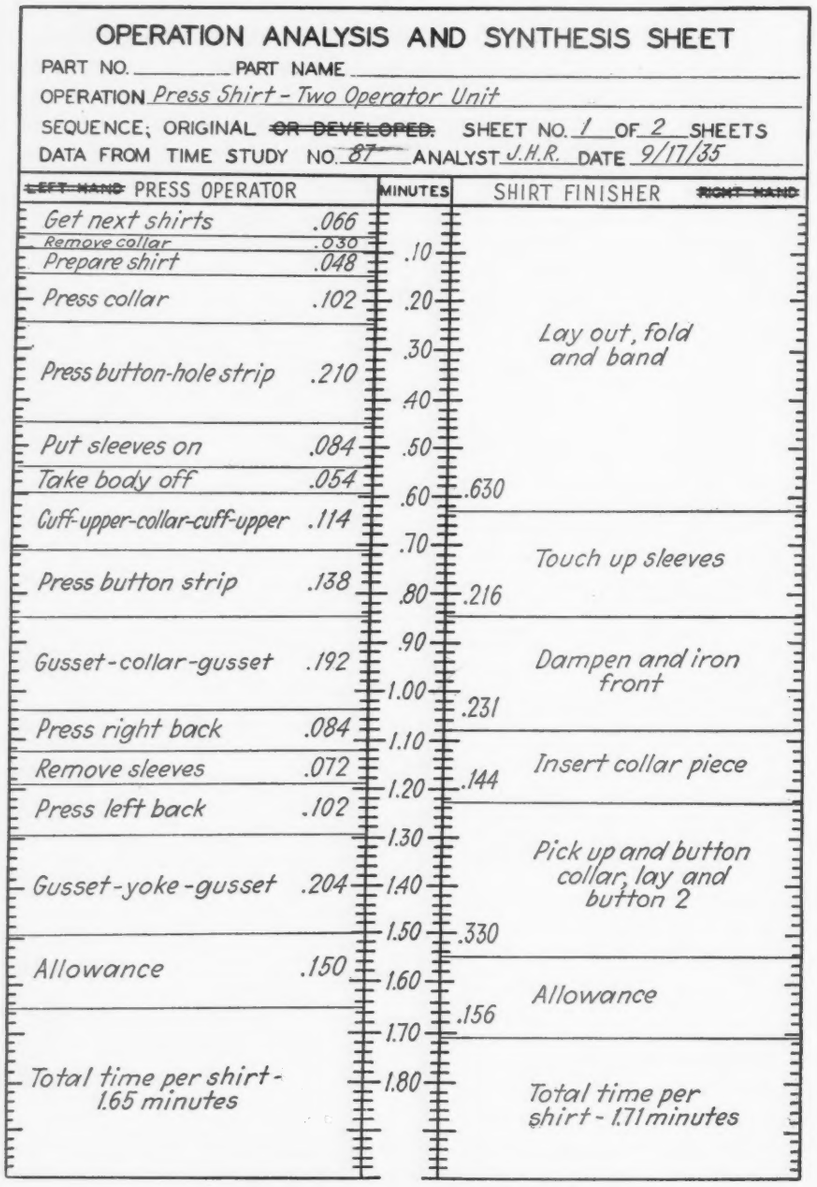


Figure 5. Here the principle used in the right- and left-hand process chart is adapted to plotting the motions of two operators—in this instance, a shirt finisher and a press operator

we must rely on the stopwatch. This is Tool No. 3, and at once the question arises: *Should the foreman use it?* Although he may not himself expect to make extensive use of the stopwatch, the foreman should nevertheless be thoroughly familiar with its application and possibilities.

Stopwatch and Chart

It should not be the objective of the instructor to give a training course in time study at this point. Rather, he should confine his efforts to the use of the stopwatch as a measuring tool—largely in connection with the process chart.

The place where the stopwatch will find its greatest application as a measuring tool will depend largely on the nature of the work. The right-hand and left-hand process chart, to be discussed later, lends itself admirably to measurements of this type. It is a chart made from visual observation, and the time groupings are usually such that they can be checked by the use of the stopwatch.

A typical chart made to balance up an operation that was part of a group assembly is shown in Figure 5. The same principle used in the right- and left-hand process chart—plotting side by side the motions of each hand, and then studying them for possible means of improvement—may be used in plotting on a time scale the operations or motions of any number of operators in a group. Only by this means can all parts of an operation be properly balanced.

One Operator Crowds the Other

In the shirt-finishing illustration, it will be seen that while the time taken by the finisher is only slightly more than that of the press operator, the difference is enough to cause the one to crowd the other. Since the team cannot exceed the slowest individual time, attention should be directed toward seeing what can be done to reduce the time taken by a finisher consistent with best quality results.

The main advantage in having foreman groups do some practice work with this measuring tool lies in their later understanding of the principles and objectives of time study. Many foremen are antagonistic toward the work done by the time-study man, not so much because they have any reason to feel that way, but mainly because they do not understand it at all.

That Hostile Attitude

Unfortunately, few time-study men take the opportunity to explain what they are doing, either to operators or to the foreman in charge of the department. It is for this reason that many time-study men encounter a hostile attitude, when actually, if the whole thing had been properly sold, they would be called in by the foreman to assist him in better management of his department, rather than be in the position of an outsider entering the department to show up some of its bad spots or weaknesses.

When this attitude prevails, real cooperation cannot be secured. I doubt if there is a single text on the subject of time study that does not at some point or other specifically emphasize the need for cooperation between the time-study man and the operator. Nevertheless, it is seldom that this condition exists in fact.

(References: March, 1932, p. 115; April, 1932, p. 165; May, 1932, p. 193; July, 1932, p. 285; Jan., 1933, p. 12; Sept., 1933, p. 351; Feb., 1934, p. 67; Aug., 1935, p. 328.)

CHAPTER EIGHT

Motion Study

TO MOST people motion study is synonymous with time study, and the latter is largely regarded as a speeding-up of the operator. There has been much written and said on the subject of the stretch-out or the speed-up, and before any real motion-study work can be done, the members of the training group must thoroughly understand what motion study is and be able to pass on the information to the people working in their departments.

Tool No. 4

There has been a great deal of misunderstanding as to what a proper working pace is. In the past, time studies were often made without any consideration at all of standardizing methods and equipment, or of providing any of the services to operators that we now know to be so essential. This meant that, to attain the standard set, the worker had to speed up, often to a pace that could not be maintained without injuring his health.

Motion study is not a speeding-up process. There is a difference between work done at high speed and work done in a hurry. Work done at high speed will be perfect work, because it is done by eliminating unnecessary motions. Work done in a hurry will be poor work, because it is a speeding-up of all operations, both necessary and unnecessary.

Any work that requires the operator to perform a task in less time than was formerly taken, without showing him how to eliminate useless and wasteful motions, is likely to require some speeding-up. As a result, the operator is forced to hurry and it is perfectly natural that resentment and perhaps opposition should occur.

Motion study, on the contrary, seeks to find the *one best way of doing a job*, and surprising as it may seem, *the best way is usually the easiest way.*

The principles are so simple that there is no reason whatever why a typical foremen's group should not be able to supply them immediately following the first meeting. Again, it must be emphasized that the subject matter discussed during these group meetings should be brought home as quickly as possible in the light of each group's own peculiar problems. It is here that motion-picture films, made on particular operations with which the group is concerned, will prove of more than ordinary assistance. If possible, each one of the principles should be illustrated in some one of the various operations performed and demonstrated before the group in order to stimulate further discussion and thinking.

In order to confine these principles of motion economy within reasonable limits, they will be taken up, first, as they apply to hand motions. These "best motion practice fundamentals" may be applied without the use of motion pictures or elaborate analysis and, when practiced, have a decided effect upon the skill of an operator.

Skill is so complex a thing that it is hard to state just how it is affected by motion economy principles, but we can, however, show how they are built around the psychology of the worker in such a manner as to capitalize on the strong human tendency to form habits, and that they induce and encourage some of the highly important factors that go to make up skill—factors which can be recognized as being ever-present in skillful manipulation of the hands. *These skill factors are consistency, rhythm of movement, precision, speed, ambidexterity, and the coordinated use of both hands simultaneously.*

The instructor should take particular care to discuss this matter of work habits with foremen and supervisors. He must emphasize that whenever one attempts to teach correct methods, one will encounter a stubborn resistance to change.

Every individual in the plant must be sold upon the need for these proper work habits. It should be pointed out that the job ahead of the average foreman is not so much one of devising brand-new methods and tools as it is of getting the workers to use, properly and consistently, the tools we now have. High operator efficiency is largely a matter of forming habits of careful and correct workmanship.

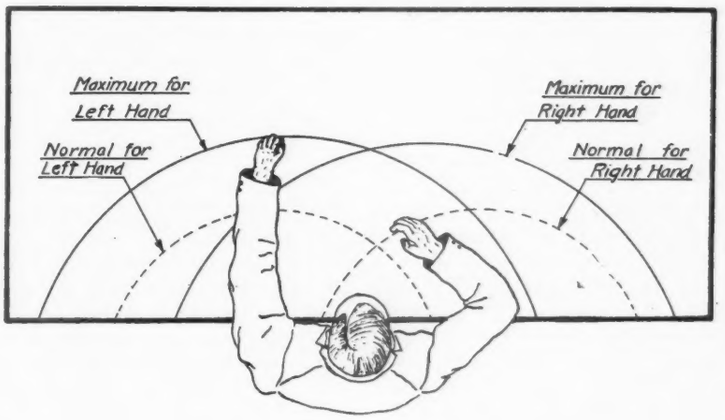
The habit tendency is capitalized by placing supplies of materials and tools used in fixed stations at proper height and in locations that will entail a minimum of effort, a minimum of distance traveled, a better distribution of motions of the right and left hand, and the use of both hands simultaneously.

Although there is admittedly a variation in natural skill of operators, it is also true that the degree of skill attained by a given operator has been greatly influenced by habit formation during the learning period and that if the fundamentals of motion economy referred to are practiced from the beginning of the learning period, a higher degree of skill will be attained.

All hand motions may be divided into five general classes:

1. Finger motions;
2. Motions that involve fingers and wrists;
3. Motions that involve fingers, wrists, and forearm;
4. Motions that involve fingers,

Figure 6. Showing definite area in horizontal plane within which materials and tools should be placed so that work may be performed with normal expenditure of energy



Photograph by courtesy of Westinghouse Electric & Manufacturing Company

Figure 7. Typical circular assembly set-up utilizing only normal working areas. Note holding fixture, pre-positioned tools, process chart used as instruction sheet

wrists, forearm, and the upper arm;

5. Motions that involve fingers, wrists, forearm, upper arm, and shoulder.

These general classifications are given in progressive order, the first class requiring least time and effort.

It is fundamental, therefore, that motions should be confined to the lowest classification with which it is possible to do the work properly.

Normal Working Areas

Considering the horizontal plane, there is a definite area within which materials and tools should be placed so that they may be handled and the work performed with a normal expenditure of energy. The area for the right hand can be drawn by extending the right arm from the shoulder and making one sweep across the table. (See Figure 6.) The area for the left hand is likewise indicated by extending the left arm forward and pivoting from the left shoulder. These two areas are called the *maximum working area,* beyond which it is possible to use only "fifth class" motions—the least desirable, as they require a disturbance of the posture.

These two areas are again divided into two areas termed *normal working areas,* indicated by arcs drawn in the same manner, but with only the forearms extended, the upper arm being more or less relaxed, and the elbow held close to the body until the end of the movement is approached, when the elbow follows the natural tendency to swing away. These zones represent the most desirable areas within which to locate materials and tools. Figure 7 shows a practical application of this principle. Note that the small containers for parts are located within the normal working areas, permitting easy reach with no disturbance of posture.

Materials and tools should therefore be located within the normal working area and with respect to the lowest classification of motions permitted by the character of the work.

Hands Should Never Hold

The human hand is the poorest thing to use as a holding device. It is surprising to see how many operations are performed with one hand used as a clamp or vise for the largest part of the cycle. A right- and left-hand process chart will demonstrate this.

The use of a simple fixture, bracket, or holding device of some sort will often free the hand from holding so that it may proceed with other constructive work.

Micromotion studies have shown the value of *drop deliveries.* By this is meant an arrangement whereby the finished article may be delivered by simply releasing it in the position in which it was completed, without the necessity of moving to dispose of it. The time saved in transporting the work to its destination is not so important as the fact that both hands are freed so that they may proceed simultaneously in unbroken rhythm —and *rhythm is an important factor in skill.*

All tools, whenever possible, should be pre-positioned. That is to say, they should be returned to a suitable holder after each use. This holder should be designed to allow rapid release, and also to permit the tool to be grasped in the position in which it is to be held during use. The small rack at the right of the operator in Figure 7 permits her to secure the various small tools ready for use without taking her eyes from the work.

Last, and wherever possible, *motions of arms should be in opposite and symmetrical directions instead of in the same direction, and should be made simultaneously.* The right- and left-hand process chart used as an instruction sheet directly in front of the operator in Figure 7 makes use of this fundamental of good motion practice.

Thinking in Terms of Motions

Motion study includes an understanding of the fundamentals of motion economy and a "motion-mindedness" that comes only through the ability to visualize the motions necessary to perform each step in an operation, and to recognize which are and which are not good motion practice rather than from thinking in terms that describe steps in the operation.

This has been one of the most common faults of time-study work in the past. Many studies have been made only with rough elemental groupings, such as "place part in machine," without any descriptive breakdown as to the distance of the box from the machine, whether the operator had to have assistance in getting the part into the machine, whether it had to be put down first on the bed of the machine, and a thousand and one other variables that might enter into the situation, and which would not in any way stimulate the thinking of either the time-study man or the operators to some improvement.

The tool that best stimulates that necessary thinking is the right- and left-hand process chart. Using the same symbols as indicated earlier, the right- and left-hand process chart is merely a detailed description of the motions entering into the per-

formance of an operation. One column shows motions performed only by the right hand; the other shows those performed by the left. Such a chart is illustrated in Figure 8.

Considerable practice should accompany this phase of instruction. Perhaps one of the best methods of handling this is to start out with a motion-picture film made on some simple operation. This film may be spliced into an endless loop, and run slowly over and over, while each member of the group learns to make a chart from it.

With the use of the film, the projector may be run very slowly until the group members attain proficiency in charting the operations. First the left-hand column must be made entirely by watching the left hand only. No attention is given at all to the right hand or the motions performed by it. When completely finished with the left hand, the right hand may then be started.

It is only by training the group to visualize an operation by this new approach that the men will be able to go out later and study operations in terms of motions. These right- and left-hand process charts may be made up in simple form, merely listing the operations, as in Figure 8, or the motions may be plotted on a scale, measured with a stopwatch. These elements enable the synthetic grouping into new classifications in a proposed method. Thus one can study and synthesize entirely new methods without actually setting them up and timing them.

It is then possible to compute the cost of the operation under the new method and be sure that a definite saving will result. This "cost-mindedness" is important, if foremen are to make the most effective use of this tool of motion economy.

Micromotion Study—Tool No. 5

There is still another tool of motion economy. It is micromotion study—Tool No. 5.

This tool is not one that the average foreman will ever use. However, he should know what it is, because in many plants its use can easily be justified.

Micromotion study is a further refinement of the right- and left-hand process chart. It is made by filming the operation, including in the picture a high-speed clock or using a constant-speed camera and special projector. Thus one can analyze the operation in terms of the fundamental motions and measure them to very small units of time.

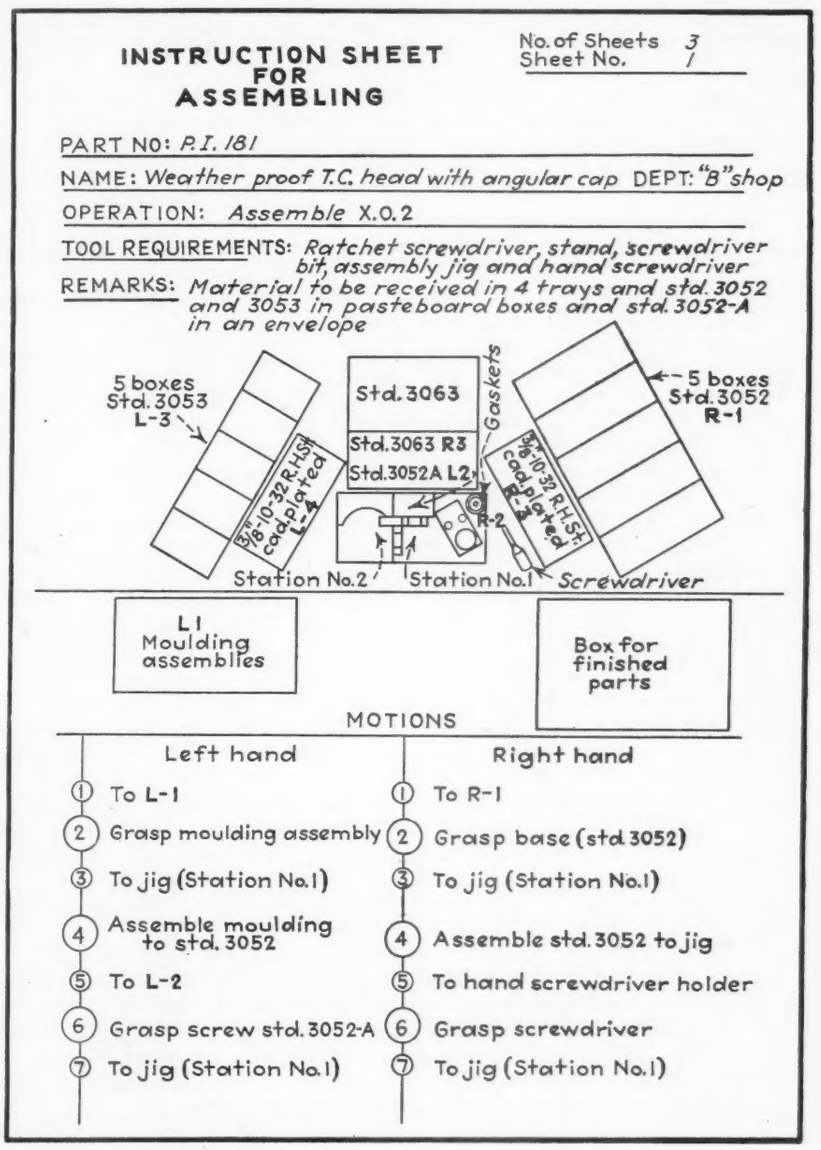
The main value of this analysis, except in plants where considerable work is performed by large numbers of operators on the same operation, lies in attaining what has previously been referred to as "motion-mindedness." There is no other way of really appreciating the importance of every single detailed motion than to sit down in front of a small motion-picture projector and run the film through one picture at a time, studying and recording the actual motions involved.

It is doubtful if in the average plant the instructor will be able to devote much time to micromotion study. It is suggested, therefore, that he secure one of the texts on the subject and familiarize himself with the details so that he can at least explain it to the group.

As with any other tool, micromotion study must pay its way, and common sense must be exercised in deciding how far to go in applying it to plant operating problems.

(References: Oct., 1930, p. 730; Jan., 1934, p. 19.; Feb., 1934, p. 67; April, 1934, p. 160; July, 1934, p. 298; Aug., 1934, p. 347; Nov., 1934, p. 487; June, 1935, p. 236; July, 1935, p. 288; Aug., 1935, pp. 341 and 350; Sept., 1935, p. 380; Oct., 1935, p. 418.)

Figure 8. Right- and left-hand process chart. Its two columns provide a detailed description of an operation, help to visualize it in terms of motions


INSTRUCTION SHEET FOR ASSEMBLING
No. of Sheets 3
Sheet No. 1
PART NO: P.I. 181
NAME: Weather proof T.C. head with angular cap DEPT: "B" shop
OPERATION: Assemble X.0.2
TOOL REQUIREMENTS: Ratchet screwdriver, stand, screwdriver bit, assembly jig and hand screwdriver
REMARKS: Material to be received in 4 trays and std. 3052 and 3053 in pasteboard boxes and std. 3052-A in an envelope
5 boxes Std. 3053 L-3
Std. 3063
Std. 3063 R3
Std. 3052A L2
Gaskets
5 boxes Std. 3052 R-1
3/8"-10-32 R.H.S.H. cad. plated L-4
R-2
Station No. 2
Station No. 1
Screwdriver
L1 Moulding assemblies
Box for finished parts
MOTIONS
Left hand
Right hand
1 To L-1
2 Grasp moulding assembly
3 To jig (Station No. 1)
4 Assemble moulding to std. 3052
5 To L-2
6 Grasp screw std. 3052-A
7 To jig (Station No. 1)
1 To R-1
2 Grasp base (std. 3052)
3 To jig (Station No. 1)
4 Assemble std. 3052 to jig
5 To hand screwdriver holder
6 Grasp screwdriver
7 To jig (Station No. 1)

CHAPTER NINE

Applications of Motion Study

THE BEST possible means of putting the training program into action is to devote at least one-half of the time to finding specific solutions to plant operating problems, work them out to completion, and then use them as case material in instructing the groups. After each of these case problems has been carried through as a group project, the ease with which further applications will be made, either in the same department or in different departments of the plant, is amazing. The questions and answers that follow will serve to point out some of these more important applications.

How does motion study apply to layout?

It is doubtful if flow process charts can be made without suggestions coming in immediately for a rearrangement of a department, perhaps of the entire plant. The charts aid in determining whether the present layout is satisfactory.

Ask the Same Four Questions

To aid in visualizing the flow of work, flow diagrams laid out to scale are usually made. These diagrams show the major life lines of the product throughout the plant, and are essential in analyzing the operations. In any event, before considering the new arrangement, the four questions on page S-139 must be asked of each symbol on the chart.

After the proposed chart has been made, we are ready for the templet layouts. When these layouts are begun, it will be found that they must go hand in hand with the proposed process charts. One may make several changes in templet layouts, which, of course, will alter the process chart. Likewise, one may make further revisions in the chart, which will possibly necessitate an entire revision of the templets.

Where are the savings to be obtained today in layout?

Many concerns are finding substantial savings in switching over from what is known as process control to product control. This merely means that instead of carrying each product through various departments, small plants within the plant are set up, so far as practicable, to manufacture that product complete in straight-line production.

Some of the advantages of product control are:

1. Reduction of manufacturing interval, hence increased turnover. It is a matter of history that the straight-line method of manufacturing, applied to the automobile industry, reduced the time interval from a matter of weeks to hours. One manufacturer who recently took a product out of the general shop and set it up for product control was able to cut down the manufacturing time from 43 to 5½ days. One of the leading manufacturers of refrigerators today is getting 45 complete turnovers per year.

2. Reduced investment in labor and materials in process. Stocks of parts, usually carried in stockrooms and at the benches of each department, are generally reduced.

3. Fixed responsibility. Supervision and inspection have less opportunity to shift the blame for inactivity or improper activity to the department previously working on the part or assembly.

4. Less handling. Straight-line layout simplifies handling, lends itself readily to the use of mechanical conveyors and other handling devices, when they are justified, and simplifies production scheduling problems. If parts are to be blanked on one press and formed on another, which is located several hundred feet away, it may be more economical to pay two millwrights $10 to move the press next to the other one than to pay a trucker $3 a day to truck the parts, even if the set-up is to be used for a matter of only a few weeks.

5. Better control of the operation. Under process control and decentralized direction, much time and effort are expended in correcting errors in the quality and quantity of the work passing through the process. By product control, with shorter manufacturing intervals, these errors are not as likely to occur in the first place. If they do, they can be corrected more quickly.

6. Elaborate inspections between departments are eliminated. It is here that a great deal of money is often spent without adding any value to the product.

7. Cost accounting, payroll administration, and production records are simplified. Many records that are duplicated under process control can be consolidated or entirely eliminated.

8. It permits the group system of wage payment, makes a department responsible for the completed product, simplifies payroll problems, adds to the incentive, goodwill, efficiency, and cooperation of the whole department, by making for a "community of interest" for the workers.

Naturally, this type of layout has its disadvantages; they must be weighed carefully before making any move:

1. It makes it difficult to operate all machines at their normal capacity, thus increasing idle machine time—a large factor if it is necessary to go out and buy new equipment to set up the department.

2. It increases capital investment, because of higher equipment requirements.

3. It complicates the matter of training and supervision. Workers, instead of knowing only one operation, or perhaps knowing how to run only one machine, must be given considerable training before they can step in and operate a group—often made up of three or four entirely different types of machines. This naturally also increases the knowledge that must be had by the machine-setters and toolsetters, and also requires a higher type of supervision.

Worth Investigation

Change from process control to product control may not be desirable in all industries, or possible in all phases of an industry. Failure, however, to analyze the problem as a whole is no doubt responsible for the small number of manufacturers who have as yet taken advantage of this particular way to lower costs.

How will motion study affect safety?

Many foremen feel that a program of motion economy may have an adverse effect upon the safety record of their plant—that safety and productive efficiency are opposed, because in the past accidents have resulted from workers being forced to speed up.

A correct understanding of what motion study really is—that it is not a speeding-up process—is essential. The prevention of accidents, just like the prevention of waste of time, energy, and materials, is largely a matter of forming habits of careful workmanship.

Safety and motion study go hand in hand. The best definition of safety is that it is the right way of

doing a job. An accident is just the result of doing something wrong. *The safe way is the right way, and the right way is the safe way.*

Does motion study affect machine and tool design?

Very definitely. In fact, in a great many plants the place to start with motion study is in the design of tools and equipment.

One often wonders if the men who design equipment even think of the motions the operator must go through in order to use it. Occasionally one sees a machine on which every and any lever can be operated without the operator taking a single step, but comparatively few machines are built with this principle in mind.

There is, however, a noticeable trend toward definite consideration of this phase of motion study. Many of the machines exhibited at the recent Machine Tool Show are controlled entirely from push buttons located on the machines, or by pendants, which give operators complete control of every movement of the machine without looking up from the work or shifting position.

Too Much Attention to the DO

Another important trend is the amount of attention that is being given to improving loading and unloading methods. Most of the efforts in past years has been expended in the direction of improving the cutting or actual operation time—the DO. This has often been carried to a point where it is only a small percentage of the handling and loading or unloading time.

Another field of application lies in reducing set-up time. In many instances improved equipment cannot be justified merely because it takes too long to make set-ups.

New devices that are receiving more and more attention for the elimination of waste motions and idle time—for both men and the machines—are the electric time meter and the motion-picture camera.

Various time meters are now available. Some of these instruments record only idle time; others give full data on all machine functions.

The motion-picture camera has applications not only in the instruction of the group in before-and-after methods, in demonstrating simple fundamentals of motion economy, and in analysis of operations, whether by the simple right- and left-hand process chart method or by a full micromotion study, but also in the study of machine and tool design. With slow motion, the mechanical action of high-speed machines may be studied, and in several instances the results have more than justified the expense. A camera now on the market takes as many as 2,500 pictures per second, has shown up faults or defects in machine functioning that could not have been detected by any other means.

Can motion study improve product design?

Naturally, one does not want to subordinate appearance or construction of a finished product merely to ease of manufacture, but study of this particular phase of product design will sometimes enable substantial reductions in manufacturing costs without any harmful effect on the product itself. In fact, such studies often result in an improved product as well as in lowered cost.

Consider Ultimate Use

Product design and motion study can also be profitably introduced to each other in the ultimate use of the product. Few manufacturers of consumer goods have given much attention to the fundamental principles of motion economy as applied to the motions involved in using their products. A little thought along this line may result in increased sales because of better customer acceptance.

Can motion study help in package design?

Again, yes. Little attention has been given to the proper design of the container or package from the angle of ease in putting the product into the package. In addition to the actual design of the package itself, there is no greater opportunity for improvement in the average plant than in the study of the packing and shipping department. A simple little thing such as taking the cover from an empty box with one hand and immediately placing it on the box which has just been filled—instead of taking the empty cover off, laying it on the table, placing the product in the box, and then picking up the cover and putting it back on—will often save as much as 35 per cent in the time taken.

Will the motion economy program help the foreman in his job of training new operators and retraining old ones?

It is here that the foreman will no doubt make the greatest use of the principles he has covered in the course. As stated before, the job is not so much one of devising new methods and tools, as of getting workers generally to use the methods and tools we now have.

Greater losses come from *not doing what we know* than from *not knowing what to do.* Ask the average foreman this question: "How much of your time is spent in just checking up to see if your men are doing what you told them to do?" And you will get the answer: "Nearly all of it."

In addition to this, the foreman is confronted at the present moment with the responsibility of breaking in new operators.

After devoting considerable attention to the subject of motion study as a means of improving manufacturing processes, one large company discovered that it was also extremely valuable in training new personnel. It was therefore decided to apply it to a finger operation that consistently showed a higher labor loss whenever a fluctuation in production made it necessary to hire additional workers.

This operation, known as trimming, consisted of removing the rind from the edge of a vulcanized rubber heel by the use of two power-driven rotary knives. The skill and finger dexterity required on the part of the operator was considerably above the average, and because the moves were faster than the eye could follow, a long period of time was usually spent by the new worker in trying to master these moves sufficiently well to earn even the guaranteed learner's rate. This resulted, first, in a large labor loss developed by the beginners; second, in a large loss in machine capacity, because it became necessary to add other shifts with extra supervision.

The discovery was made that even the oldest and most efficient trimmers did not know the finger moves they made in spinning the heel between the knives. They had developed these moves automatically after long months of practice. All beginners would do the same if given enough time.

Sketches Showed Moves

To shorten this learning period, a detailed motion study of the movements of the hands and fingers was made. Sketches were made showing the position of the finger while spinning the heel. A careful explanation of the pictures and study was given to the new workers before they started on the job. The importance

of following the moves as outlined by the study was emphasized, and it was proved that it is practically impossible to get a free, smooth trim by any other method.

Number of heels trimmed per hour was not stressed. The plan of instruction was first to teach the correct moves, then to get quality workmanship, and at last attain the necessary speeds. The results of this plan were satisfactory, both to management and to the workers.

Process Charts for Training

In some plants, process charts are used for instruction. One electrical concern makes up simple instruction sheets in chart form (as in Figure 8) on all operations. When the operators secure the materials and tools for the assembly or operation, they also draw out standard parts and containers as called for on the process chart that accompanies the drawing or work order. It is then a simple matter to follow through once or twice, slowly, according to the instructions, until the correct method has been mastered. After that, speed is soon acquired.

This practice not only secures proper performance on each job, but soon starts the worker thinking along lines of motion economy. As a result, suggestions for improvement of existing methods, as well as on new jobs, are received. In some plants these right- and left-hand process charts are placed directly in front of the operator and used to insure proper performance until the right sequence of motion becomes a fixed habit. Such a chart is shown in Figure 8. In one instance, as a result of common-sense motion study, coupled with the training method just described, a reduction of 60 per cent in assembly time was secured. The circular bins (Figure 8) are so arranged that all the work is within the maximum working area, keeping the body in balance and reducing fatigue. The piece is ejected by a foot lever.

In the assembly operation shown in Figure 8, principles of motion economy were applied, and a right- and left-hand chart drawn up. There are 80 operations with the left hand, 91 with the right, assembling 44 different pieces, and yet they are so simply and clearly described by this method that new operators are being started on the operations with the process chart. Incidentally, the new method takes between 4 and 5 minutes, as against 45, with the quality materially improved.

It is not an uncommon occurrence, even when a time standard is properly and fairly set, to find operators failing to make out on it. The man who set the standard based it on the assumption that the operation would be performed in the correct manner. Failure to write proper instructions, to follow through and see that these instructions are carried out, or reversion to older methods as time and force of habit have their effect, may often be responsible. If process charts are made before time studies, elemental values may be tied in with the process chart. This failure to come up to standard may then be checked with the operator, and the difficulty remedied.

Motion Pictures Also Used

In another plant, operator training has been extended to the point where motion pictures have been used perhaps more fully than in many. Right- and left-hand process charts made on certain operations were the basis of discussions held by various supervisory groups. Foremen and foreladies discussed the various charts from the standpoint of the motion used, and finally evolved a method that seemed to everyone present the one best. Then these new methods were taught to a few of the operators.

When these operators had acquired skill, process charts were again made and analyzed. Final refinement through the use of the process chart was followed by filming some of the best operators. These films were then shown to various groups. In fact, curtained booths were set up right in the production areas, and operators came in before each shift and looked over the loops of film as they were run through. It was not at all uncommon to have several operators involved in quite a discussion as to just exactly which fingers should be used in tying a certain knot. Several might feel that their own method was superior to the one that had been agreed upon by the group. This discussion was encouraged up to the point where the one best way could be selected, and then all were expected to learn this method and become proficient at it.

In another plant where motion study is being used to aid operator training, both motion-picture films and still enlargements of frames from these films are used. The enlargements are pasted on cards which give explicit right- and left-hand instructions for each detailed part of the operation. After the members of the group have looked at the films and had an opportunity to ask all the questions concerning the method, they are then given these instruction cards which can be taken right out on the job.

Surprising results have been obtained from work of this sort. In one instance training time has been cut down to one-third of that formerly taken. In another plant even higher average efficiency is being obtained on a group of new operators at the end of three weeks, than was previously attained after sixteen weeks of training. Many other instances of this sort testify to the value of a motion-economy program in helping the foreman in what is perhaps his biggest problem today.

One of the most important jobs that industry has on its hands today is to develop cooperation between industry and its employees. Every industrialist knows that the success of his business depends directly on the developed ability of his workers. He must also recognize that training is a responsibility of management, and cannot be left to haphazard means.

Not Everyone Can Teach

Executives and supervisors are usually not qualified to do the training job. Even knowledge of the job and ability to perform it in every detail does not mean that the foreman or supervisor can teach it efficiently, either in whole or in part, to others. Teaching is in itself a profession, as much so as any other art, and the individual foreman must be taught to teach. Whether it is safety, or motion study, or sound thinking, we must not only give the foreman the facts, but we must also help him in getting them across to his operators.

Only through this cooperative effort on the part of everyone in the plant shall we ever attain the objective—*a better product at a lower cost and at the right time.*

(References: Dec., 1931, p. 797; May, 1933, p. 175; July, 1933, p. 265; Sept., 1933, p. 351; Jan., 1934, p. 19; March, 1934, p. 114; Sept., 1934, pp. 384 and 393; Dec., 1934, p. 538; Jan., 1935, p. 16; Feb., 1935, p. 60; March, p. 99.)

MAINTENANCE ORGANIZATION AND MANAGEMENT

AUTHOR

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Editor

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CHAPTER ONE

What Maintenance Is

LET'S get at the definition of maintenance first, so we'll be writing and thinking about the same thing.

As is true with almost all functions, the function of maintenance does not lend itself to brief, simple, yet inclusive definition.

Suppose we write a formula that appears to be broad enough to cover the function and then try to amplify it to make it specific. Let's begin with the simplest broad statement that we can think of:

(1) *Maintenance in manufacturing plants is the function of keeping structures, equipment, and services in condition for efficient plant operation.*

Taken literally, this definition can be interpreted to presuppose that all structures, equipment, and services are provided before the maintenance function becomes operative.

Such, indeed, might be the case. Yet experience indicates that this practice is not usual and, indeed, not advisable. The very duty of doing work upon buildings and equipment implies that the maintenance operatives must have on hand certain other equipment and supplies. Obviously maintenance partakes of the function of *procurement.*

In the interest of low operating costs the maintenance operatives must supply the kinds of motive equipment, power transmission equipment, and control equipment that are best adapted to specific and individual production machines. This means that they partake of the responsibility for *selection* of the equipment that is auxiliary to production.

Because their responsibility includes the application of the transmission and control equipment, maintenance operatives are automatically charged with the responsibility for the *installation* of this equipment.

Our definition, therefore, grows, with this addition:

(2) *The personnel in charge of maintenance has a primary interest in the selection, installation, operation, and upkeep of the plant equipment needed to transmit, apply, and control the mechanical power and electrical energy used in operating the production equipment; and in the procurement and use of the supplies and tools required for the upkeep of buildings.*

Our definition (1) said that maintenance must keep *services* in condition. By services we mean the supply of light, heat, water, gas, air, signaling, communication, protection; the supply of transportation for materials and products into and out of the plant among the production machines while processing is going on, and into and out of stores.

The impossibility of maintaining the services involving light, heat, water, and so on without having at hand the necessary wiring, lamps, reflectors, heaters, piping, valves, and similar equipment indicates that here too, the maintenance personnel has a primary interest in procurement, with all that it involves and with *stores* as well.

There can be a different situation with regard to transportation and handling. All the equipment can be made available to the maintenance

WHILE Lewis Carroll put a lot of nonsense in "Alice in Wonderland," and in "Through the Looking Glass," he forcefully brings to mind certain fundamental truths. Alice and the Red Queen had been running at top speed, hand-in-hand, for some time, and then sat down under a tree to rest. Alice said, "I believe we are still just where we started from. In my country, when we run we get somewhere else." The Red Queen said, "In this country, we have to run as fast as ever we can to stay in the same place. If we want to get anywhere else, we have to run twice as fast as that." Which is about the situation in industrial plants in this country, for only strenuous effort, long sustained, will hold a plant in a commanding position

department along with instructions to keep it in operating condition. This means that procurement, so far as this classification of equipment is concerned, is not necessarily a part of the maintenance function—although it may be.

However, that qualification applies to the equipment only—not to the supplies and replacement parts needed in the actual upkeep work, such as lubricants, bearings, batteries, fuses, switches, idlers.

We are now in position to add a third part to our definition:

(3) *The maintenance personnel is responsible for maintaining all shop services, including transportation and materials handling, and for the procurement, storing, and disbursement of the necessary supplies and replacement parts.*

Of course the production equipment itself does not give service without attention. It has to be serviced—that is, inspected, lubricated, cleaned, repaired. These duties, obviously, are a part of upkeep.

In order that these duties may be carried on as inexpensively as possible, there must be regularity of performance. The same is true of the tributary equipment previously mentioned — electrical motive and control, and mechanical power transmission equipment. It is evident that inspection and performance *records* are required; they can be made only by the maintenance personnel.

All of the work of the maintenance department must be done as a result of *orders*. Some of the orders will be verbal, some will be written. Some will originate within the maintenance department, some without. In either case, there must exist some authority by which these orders are distributed to the personnel, their execution is seen to, and they are cleared back to the point of origin. This means that a maintenance *executive* is required.

Because the work of the department must be systematic, and must be done in accordance with time requirements, *planning and scheduling* are necessary. And because of the paper work involved, *clerical* services are required.

We are now ready to add a fourth part to our definition of the maintenance function:

(4) *The maintenance personnel is responsible for the upkeep of all production equipment, its regular inspection, cleaning, lubrication, and repair; for the keeping of inspection and performance records of auxiliary equipment; for the proper supervision, planning, and scheduling of maintenance work; and for the clerical work appurtenant thereto.*

Throughout all the items of maintenance responsibility that have been enumerated there runs the implication of maintenance cost. As will be seen in following chapters, control of maintenance to determine permissible costs and operation within those costs is a partial function of the maintenance department. This fact gives the final addition to our definition:

(5) *The maintenance personnel is concerned with the recording, analysis, estimating, and control of maintenance costs.*

Doubtless the assembled definition can be regarded by plant operating executives in some of the largest plants as not being sufficiently inclusive. Executives of small plants may consider it cumbersome. The answer to both must be that the definition is developed to be basic and to lend itself to addition or subtraction as specific conditions may require.

There is every reason why the individual plant executive should write his own definition of maintenance as carried on in *his* plant, using the definition given here as the structure about which his own definition is to be built.

Certain it is that the preparation of such a definition is the beginning of functional analysis for maintenance. Where a definition cannot be written, either the function itself does not have definite lines or the executive does not understand what those lines are.

At any rate, here is the completed definition:

Maintenance in manufacturing plants is the function of keeping structures, equipment, and services in condition for efficient plant operation.

The maintenance personnel has a primary interest in the selection, installation, operation, and upkeep of the plant equipment required to transmit, apply, and control the mechanical power and electrical energy used in operating the production equipment; and in the procurement and use of the supplies and tools required for the upkeep of buildings.

The maintenance personnel is responsible for maintaining all shop services, including transportation and materials handling; and for the procurement, storing, and disbursement of the necessary supplies and replacement parts.

The maintenance personnel is responsible for the upkeep of all production equipment, its regular inspection, cleaning, lubrication, and repair; for the keeping of inspection and performance records of auxiliary equipment; for the proper supervision, planning, and scheduling of maintenance work; and for the clerical work appurtenant thereto.

The maintenance personnel is concerned with the recording, analysis, estimating, and control of maintenance costs.

CHAPTER TWO

Jobs and Personnel

NOW, who does the maintenance work? What titles do these people have? What is their relationship to other people in the plant who do other work? And what is the relationship between the work they do and the work of other people?

Jobs, Rather Than Titles

We should first get rid of any ideas we may have that titles and jobs *must* fit, although it is true that titles *should* indicate the kinds of work being done by the individuals holding them.

We should then recognize that the function of maintenance — like the functions of production and sales, for example—exists and must be served no matter what titles are carried by the personnel engaged in serving it.

To illustrate this point, consider a very small plant—one of 25 men—engaged in jobbing work. Of course there is a "boss." He may be called simply the boss, or he may be called the president. If the business is incorporated, undoubtedly he will carry the title of president, if he is the owner. If not incorporated, and he is still the owner, he may actually have no title. He may perform all the functions involved in financing the business, selling the product, managing the plant, managing the office, and purchasing; yet his title, or lack of title, will not indicate that he does all those things.

Under corporate management he might be, in effect, a superintendent, or foreman, in spite of his title of president. Under such conditions the owners of the business might be people outside the plant who furnish capital, make the sales, do the purchasing, and determine policies.

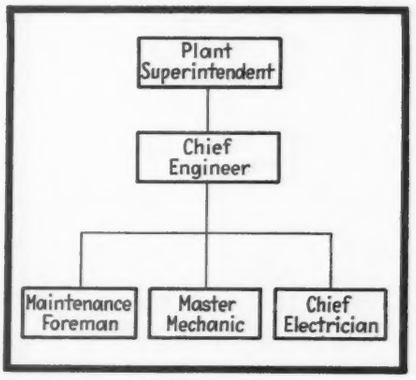


Figure 2

In this little 25-man plant each worker might operate his own machine and also do all the work in connection with cleaning, lubricating, and repairing it. He might even transport the material he was to work on from the simple store, or pile, in one end of the shop, to his machine—and then to the pile of finished work after he was through with it. When he did those things, he would be performing at least parts of the functions of production and maintenance.

Functions Will Overlap

The details of the possible arrangements in our small shop could be visualized in an infinite number of combinations. If the boss merely hung his orders on a hook, and each man thumbed through those orders and then used his own judgment as to what order he worked on, he would be engaging in the function of management, because he would be doing planning and scheduling.

If each worker looked after his own lighting, kept the floor in condition around his machine, did his share of the shop cleaning, and shared in other similar work, he would be participating in another phase of maintenance work.

Use a Minimum of Red Tape

It is in the small shop where the lack of distinction between functions will be most pronounced. Which is as it should be. There is no sense in unnecessary red-tape and complications. The main objective of everybody in the plant is to get out the work; to keep the equipment in such condition that there will never be a hold-up because of breakdown; and to have the conditions of light,

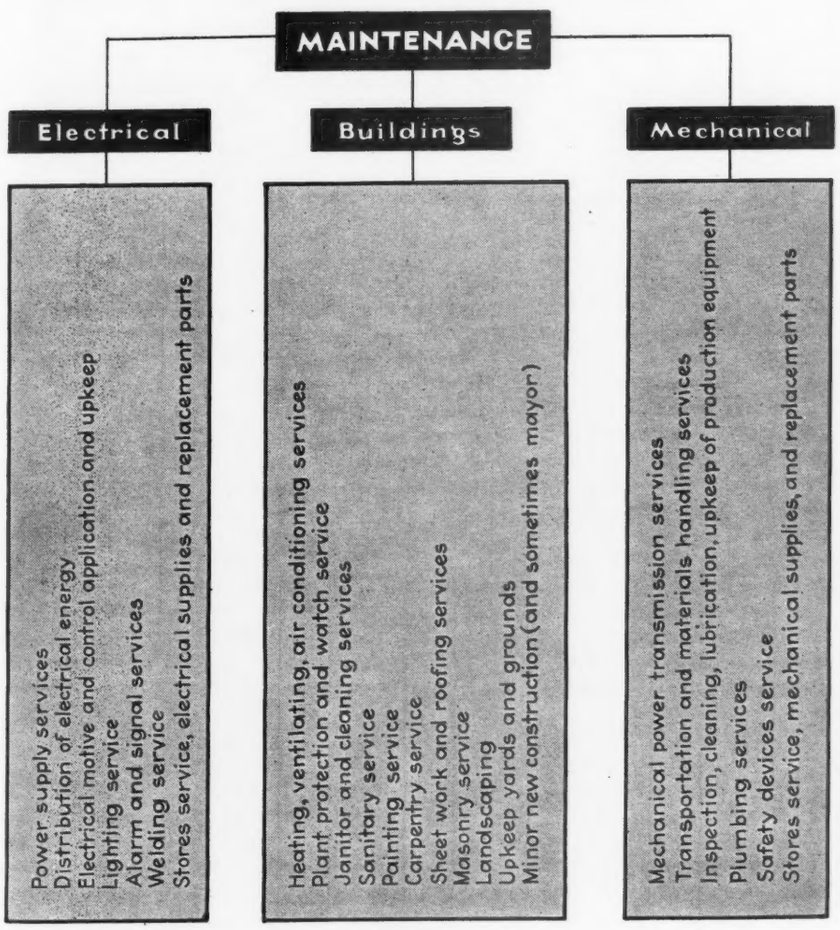


Figure 1

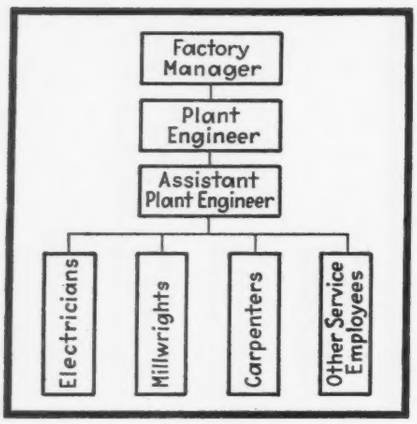


Figure 3

heat, and so on such that workers will not be inconvenienced, and therefore will do the work speedily within the tolerances required.

Exactly the same objectives exist in the plants of medium size, large plants, and very large plants. But right there is where the importance of differentiating between functions comes in. As plants increase in size, details multiply, interrelations of functions become more complicated, less of the physical equipment can be under the eye of the individual, and it becomes necessary to assign specific obligations to specific people.

Define Jobs, Set Titles

To differentiate, we must define. And having defined, it is advisable to *label*, so that definitions will stay in line. It is, therefore, important that at least an approach be made to fit titles to jobs.

There is no set of titles for maintenance jobs that can be applied in every plant, just as there is no set of titles that can be applied to any government no matter how set up—as democracy, monarchy, or fascist state. The matter of most importance in each case is that the personnel within the plant — or within the country — understand what titles apply to what duties.

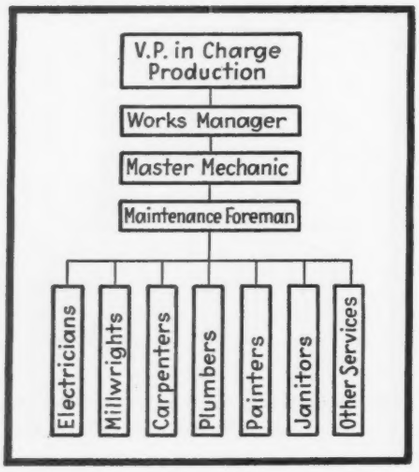


Figure 4

Actual Plant Set-ups

In our definition we outlined the responsibilities that are involved in the maintenance function. In Figure 1 the kinds of work to which these responsibilities apply are shown in chart form.

Shortly before the depression that began late in 1929 I surveyed some 40 or 50 plants to find out what labels, or titles, had been allocated to the men in charge of these kinds of work. From the data collected I picked the reports on 15 plants in order to have a wide spread in number of employees and motor horsepower, and a wide variety of products.

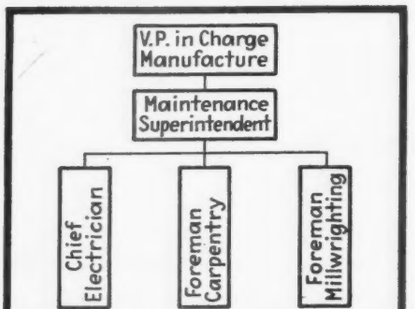


Figure 5

Number of employees varied from 160 to 15,000; motor horsepower from 315 to 18,000; and products included paper, confectionery, clothes wringers, mouse traps, rubber products, locomotive cranes, linoleum, steam shovels, cameras, gasoline motors, nitrocellulose, acid, interplant communication systems, vacuum cleaners, steel building materials, automobiles, cash registers.

Little Uniformity in Titles

The 15 reports showed lack of uniformity as to the titles of the men in charge of the maintenance activities charted in Figure 1. Seven used the title of plant engineer; 2, master mechanic; 1, maintenance superintendent; 1, maintenance engineer; 1, chief engineer; 1, chief mechanical engineer; 1, three titles for three men with equal standing (buildings superintendent, chief electrician, machinery maintenance superintendent); 1, two titles for two men with equal standing (maintenance foreman, mechanical and machine; maintenance foreman, electrical). These factual reports conform with my statement, "There is no set of titles for maintenance jobs that can be applied in every plant."

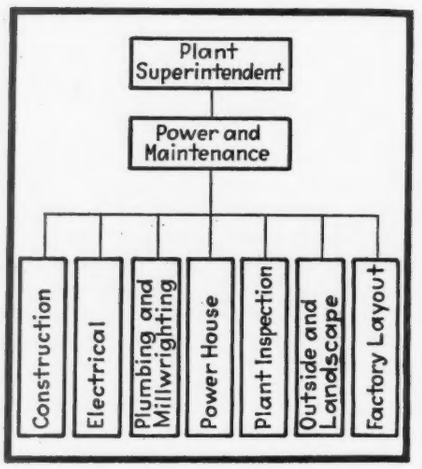


Figure 6

Line of Authority Definite

There was, however, a remarkable unanimity among these plants as to line of authority. One of these heads of maintenance reported to the president; 1 to the vice-president in charge of manufacture; 1 to the assistant superintendent; 1 to the works manager; 1 to the general works manager; 1 to the chief engineer; 1 to the general superintendent; 3 to the plant superintendent; 4 to the factory manager; and 1 to two men, the chief engineer and the general superintendent.

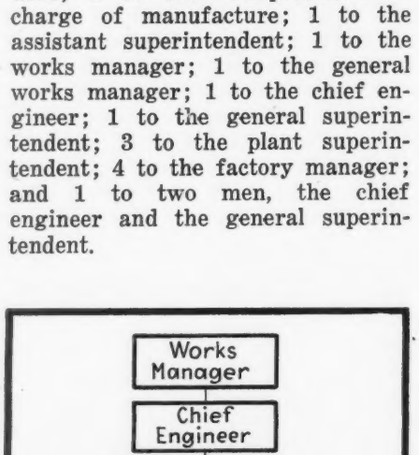


Figure 7

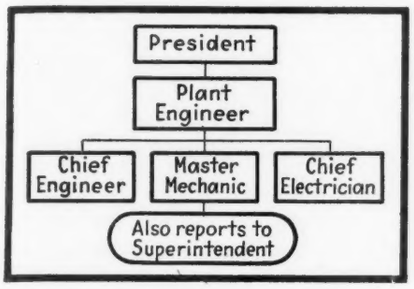


Figure 8

So far as these 15 plants are concerned, it is not difficult to reach the conclusion:

The men responsible for the maintenance function report to the executive in charge of factory management.

In my opinion that is the preferred arrangement. I visualize a chief of plant operation—a factory manager. Reporting directly to him are the heads of the three major divisions of manufacturing plant work: Production, maintenance, inspection.

Maintenance Can Appeal

If this arrangement is followed, the maintenance department always has open to it a court of appeal if it is faced by the conviction that requests by another department are unreasonable or impossible of fulfillment. There need be no interference with the cooperation that is necessary between maintenance and other departments. At the same time there is not likely to arise a situation in which the maintenance department can be made a source of alibi, or a scapegoat for negligence or poor judgment on the part of other departments.

The maintenance department cannot be an isolationist department. The nature of maintenance work prevents that condition. Much of the work that it does originates in other departments. Requests for that work to be done—they may be called requests, or requisitions, or orders—correspond to the orders received by the factory for its product. The other departments are the customers of the maintenance department.

Maintenance Sells Its Services

This analogy can be carried further, but with variations on the usual seller-customer relationship. If the customer is not satisfied with the maintenance service rendered, he still has to come back to the same seller—but he may ask for a change in personnel. On the other hand, if the customer does not have to pay for what he gets—that is, if the costing procedure is not such that his own department suffers for errors in judgment and for unreasonable demands—the seller is at such disadvantage that he cannot operate his department (his business) on a balanced, low-cost basis.

Which is more important in an automobile, the motor or the wheels? Which is more important in a factory, the production department or the maintenance department? In neither case can the one perform its function without the other. In each case both must work together. And in both instances control is needed at the wheel, the clutch, and the brake.

Figures 2 to 9, interspersed in the text of this chapter, are examples of actual set-ups in effect in factories making a variety of products. Some of these charts show titles of personnel, and some show jobs. All show the line of authority back to the factory manager. It will be seen that while there is almost uniform definition of jobs and lines of authority, titles differ.

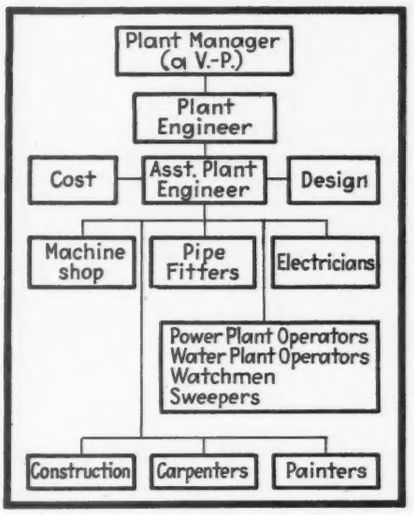


Figure 9

CHAPTER THREE

Maintenance Order Forms

THE MAINTENANCE function has been analyzed. The jobs to be done have been determined. The relationship of the maintenance personnel to other personnel in the plant has been decided upon. The next logical step is one of management. It is to establish the machinery by which the maintenance work itself is created and carried through the steps necessary to a successful conclusion.

Order forms are the inanimate part of this machinery. They are needed in all but the very small shops. Wherever there is division

CHG. ACC'T. _____

MAINTENANCE WORK ORDER

DEPT. _____ WILL PLEASE PERFORM THE FOLLOWING WORK

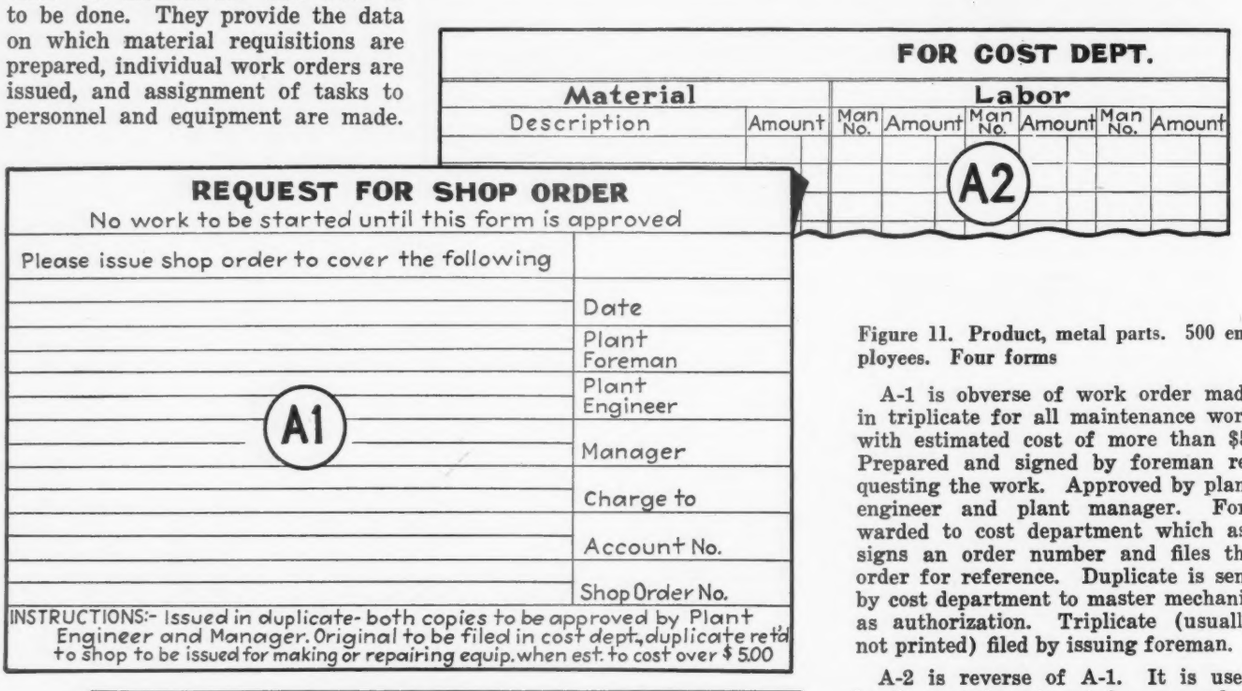
DESCRIPTION:-	FOR MAINT. DEPT.		
	Date	Man	Hours
DATE _____ SIGNED _____ DEPT. _____			

Figure 10. Product, hardware. 250 employees. One form. Work order is made in duplicate by the foreman of the department requesting the work. Original goes to maintenance, duplicate is retained by the foreman. Maintenance uses a requisition form standard for the shop, to draw material from stores. When work is finished, filled-in work order goes to the cost department

of responsibility; wherever there is allocation of overhead costs; wherever maintenance work is estimated in advance — there written records are necessary.

Several purposes are served by maintenance orders. They establish for both maintenance and management the information that work is to be done. They provide the data on which material requisitions are prepared, individual work orders are issued, and assignment of tasks to personnel and equipment are made. When the work has been completed, and all entries have been properly made, they comprise records that serve the head of the maintenance department in his control activities and the cost department in expense allocation.

G. I. Ross, management engineer, has published the order forms shown in Figures 10 to 14. He selected them because they are forms in actual use; because they cover plants ranging in size from 250 to 6,000 employees; and because the products are similar enough to allow for fair comparison of the systems.



FOR COST DEPT.

Material		Labor					
Description	Amount	Man No.	Amount	Man No.	Amount	Man No.	Amount

A2

REQUEST FOR SHOP ORDER

No work to be started until this form is approved

Please issue shop order to cover the following

Date

Plant Foreman

Plant Engineer

Manager

Charge to

Account No.

Shop Order No.

A1

INSTRUCTIONS:- Issued in duplicate- both copies to be approved by Plant Engineer and Manager. Original to be filed in cost dept., duplicate retd to shop to be issued for making or repairing equip. when est. to cost over $ 5.00

Date	Man No.	Hrs.	Date	Man No.	Hrs.	Date	Man No.	Hrs.

A4

REPAIR RECORD

Name of machine _____ Mach. No. _____

Name and number of tool, fixture, or part _____

Material used _____ Weight _____

A3

Notes:- _____

Shop Order No. _____ Account No. _____

Charge to Dept. No. _____ Approved _____ Date _____

Figure 11. Product, metal parts. 500 employees. Four forms

A-1 is obverse of work order made in triplicate for all maintenance work with estimated cost of more than $5. Prepared and signed by foreman requesting the work. Approved by plant engineer and plant manager. Forwarded to cost department which assigns an order number and files the order for reference. Duplicate is sent by cost department to master mechanic as authorization. Triplicate (usually not printed) filed by issuing foreman.

A-2 is reverse of A-1. It is used by the cost department for accumulating maintenance costs. Cost department sends these data to master mechanic who uses them to prepare his repair record.

A-3 is master mechanic's repair record form.

A-4 is reverse of A-3. On it repair time is recorded.

Part of Figure 12

Date

Issued to Dept.

Date	Instructions
Acc'ts Number	
Dept. Charged	
Estimated Time	
Planned Start	
Planned Finish	
Class Man	Job Authorized _____

A5

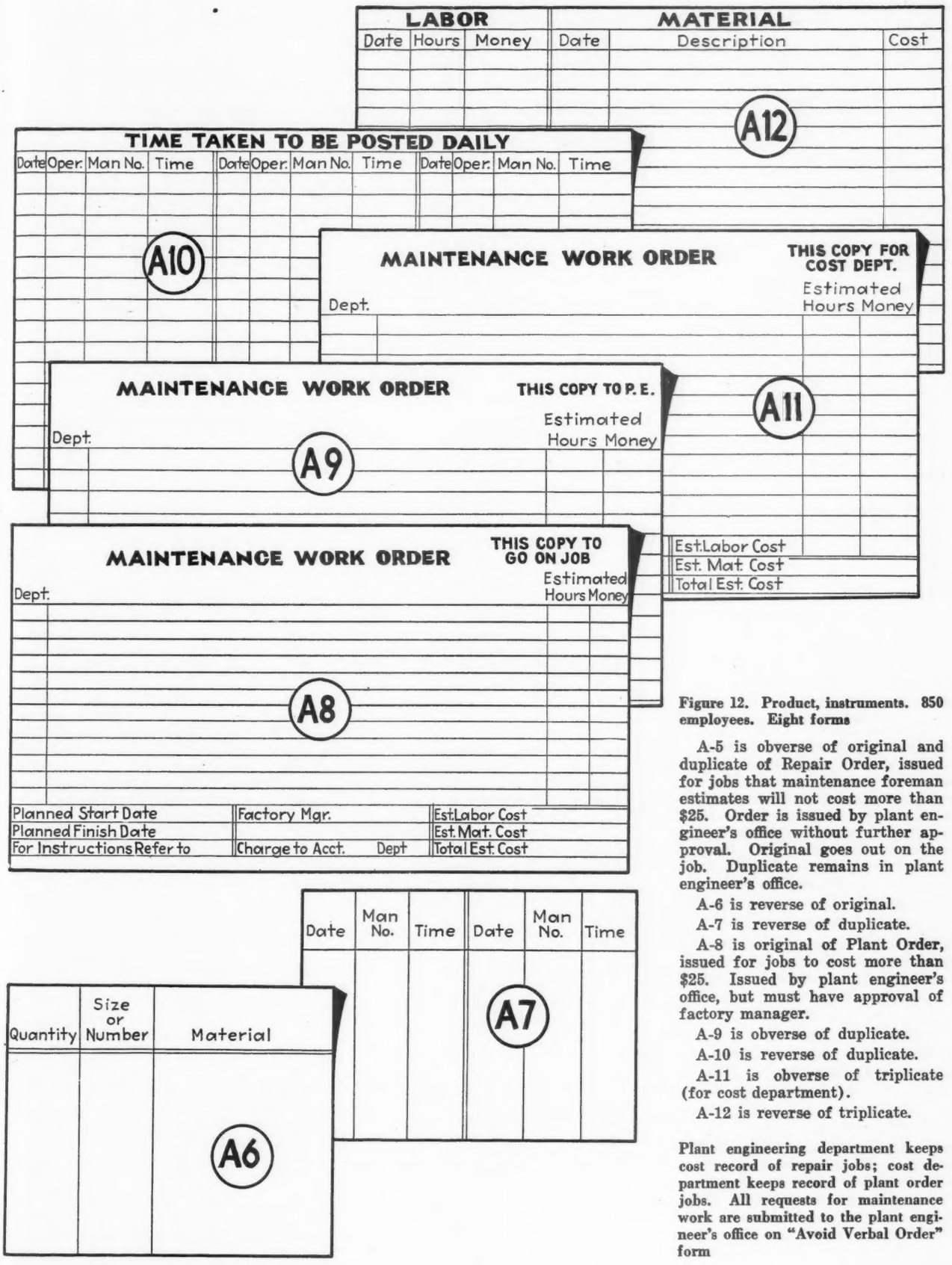


Figure 12. Product, instruments. 850 employees. Eight forms

A-5 is obverse of original and duplicate of Repair Order, issued for jobs that maintenance foreman estimates will not cost more than $25. Order is issued by plant engineer's office without further approval. Original goes out on the job. Duplicate remains in plant engineer's office.

A-6 is reverse of original.

A-7 is reverse of duplicate.

A-8 is original of Plant Order, issued for jobs to cost more than $25. Issued by plant engineer's office, but must have approval of factory manager.

A-9 is obverse of duplicate.

A-10 is reverse of duplicate.

A-11 is obverse of triplicate (for cost department).

A-12 is reverse of triplicate.

Plant engineering department keeps cost record of repair jobs; cost department keeps record of plant order jobs. All requests for maintenance work are submitted to the plant engineer's office on "Avoid Verbal Order" form

PLANT ORDER No.	DEPARTMENT	MACH. No.	Date of Order Date Completed

Department.....will please execute the following order

Chaged Acct.	Estimated Cost	Appropriation No.
A13	Signed	Plant Engineer
	Entered	Works Accountant

PLANT ORDER No. A	CHARGE TO DEPT.	MACH. No.	DATE OF ORDER
			Date of completion

Dept. _____ will execute the following order

A14

Checked Approved

Material	Value	Labor	Hrs. Value
A15			
Expense @ %		Factory Expense @ %	
Total Material and Expense		Total Lab. and Fact. Expense	
		Aggregate	

S. O. No.	Deliver to Dept.		Mach. No.	Job No.	Date
P. O. No.	Charge to Dept.				

Department..... will please execute the following order and charge all labor and material to above Dept. and Order No.

A16 **SUB PLANT ORDER**

Order No.	Deliver to Dept.		Mach. No.		Foreman	Date
Plant O.No.	Charge to Dept.		Report to			

Quantity	Description	Value
	A17	

Delivered by Received by

Only one item on a card **MATERIAL DELIVERED CARD**

DRAWING OF MACHINES A18

Drawing No.	Parts	Drawing No.	Parts

DATE BOUGHT	Purchase Price	Freight and Erect.	Total Cost	Purchase P. O.	Builder's Mach. No	Our Mach. No.
NAME						Spec. File No.
SIZE						Rate of Dept.
CAPACITY			A19			Height
MAKER						Floor Space
BOUGHT OF						Weight
BELT DRIVE	Pulley Size	Pulley Speed	Max. Hp.		Average Hp.	Friction Hp.
MOTOR DRIVE	Motor No.	Motor Speed	Motor Hp.		Motor Pulley	

Building No.	Dept. No.	Moved on P. O.	Date Moved	Building No.	Dept. No.	Moved on P. O.	Date Moved

Figure 13: Product, metal parts and assemblies. 2,500 employees. Seven forms. Maintenance expenditures are classified as follows:

(a) Current expense chargeable to the manufacturing departments. This is charged to departmental sub-accounts.

(b) Current expense chargeable to some item of equipment and to some particular department. This is charged on yearly plant orders.

(c) Improvements to plant which will be capitalized. These are charged to individual plant orders.

(d) Large maintenance jobs the cost of which is to be deferred over several months. These are charged to individual plant orders

A-13 is Plant Order, issued by plant engineer's office for maintenance expenditure not chargeable to specific departmental account. (If expense for labor, material, and overhead will exceed $100, must be approved by plant engineer and factory superintendent. If to exceed $300, an appropriation must be secured.) Original to master mechanic, stamped "completed" after job is finished, returned to plant engineer, filed with triplicate. Duplicate to cost department. Triplicate retained by plant engineer, withdrawn from active job file upon return of original; cost obtained from cost department and noted on form; filed with original in "completed" file.

A-14 is obverse of "A" Plant Order for moving machinery.

A-15 is reverse, on which cost data are listed.

A-16 is Sub-Plant Order, issued by the foreman of any department for maintenance chargeable to the current yearly plant order expense of that department. Original to master mechanic, whose clerk adds job number, stamps date received, and notes what group will do the work. Filed on control board. Sent to timekeeper upon completion of job. Returned and filed in master mechanic's office. Duplicate to master mechanic, to his control board, to worker. Signed by requesting foreman upon completion, returned to master mechanic. Triplicate retained by issuer.

A-17 is the Material Requisition for use of maintenance workers; must be signed by master mechanic. .

A-18 is obverse of Machine Record Card, prepared in duplicate when purchase requisition and installation order are issued. Cost of equipment and installation, also equipment data, posted. Original filed by department number, duplicate by machine number.

A-19 is reverse of Machine Record Card.

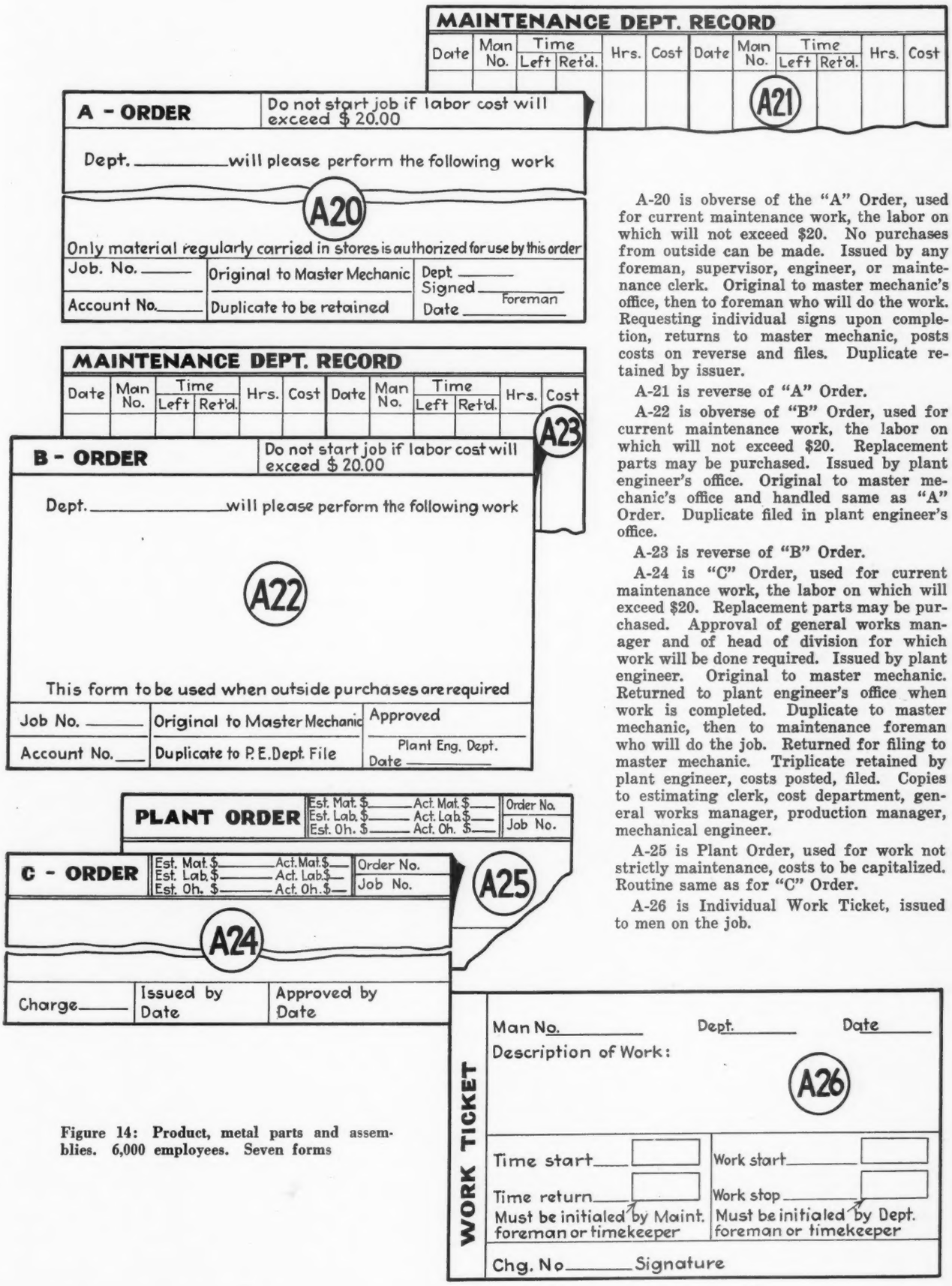


Figure 14: **Product, metal parts and assemblies. 6,000 employees. Seven forms**

A-20 is obverse of the "A" Order, used for current maintenance work, the labor on which will not exceed $20. No purchases from outside can be made. Issued by any foreman, supervisor, engineer, or maintenance clerk. Original to master mechanic's office, then to foreman who will do the work. Requesting individual signs upon completion, returns to master mechanic, posts costs on reverse and files. Duplicate retained by issuer.

A-21 is reverse of "A" Order.

A-22 is obverse of "B" Order, used for current maintenance work, the labor on which will not exceed $20. Replacement parts may be purchased. Issued by plant engineer's office. Original to master mechanic's office and handled same as "A" Order. Duplicate filed in plant engineer's office.

A-23 is reverse of "B" Order.

A-24 is "C" Order, used for current maintenance work, the labor on which will exceed $20. Replacement parts may be purchased. Approval of general works manager and of head of division for which work will be done required. Issued by plant engineer. Original to master mechanic. Returned to plant engineer's office when work is completed. Duplicate to master mechanic, then to maintenance foreman who will do the job. Returned for filing to master mechanic. Triplicate retained by plant engineer, costs posted, filed. Copies to estimating clerk, cost department, general works manager, production manager, mechanical engineer.

A-25 is Plant Order, used for work not strictly maintenance, costs to be capitalized. Routine same as for "C" Order.

A-26 is Individual Work Ticket, issued to men on the job.

In plants with more than 6,000 employees the maintenance order planning and routine are likely to differ only in detail. It is probable that there will be more forms. Complications in procedure are likely to creep in because of the inability to have all maintenance activities centralized, or because there are several plants in different localities. It is not difficult for management to make the necessary extensions if the basic procedure in the smaller plants as outlined here is understood.

So much attention has been given to the order forms because they constitute the machinery by which maintenance procedure is controlled. It is almost impossible to install a good maintenance order system if the line of authority meanders and the conception of allocation of duties is hazy.

One of the almost certain results, then, of management's determined effort to define and regulate the routine of maintenance is the revision of executive arrangement if it is at fault.

Also Results in Cost Control

Another common result is the determination of actual maintenance costs, with their eventual control. The opportunity for saving (and therefore the lowering of product cost) is tremendous in the plant that has hit-and-miss maintenance organization and management.

For details of a very carefully planned and applied system of maintenance control the reader is referred to a series of articles, "Getting Costs—and Keeping Control—of Maintenance," by Carl G. Wyder, Planning Engineer, Textile Dyeing and Printing Company of America, Inc., Fair Lawn, N. J., published in *Factory* for March, April, and May, 1934.

CHAPTER FOUR

Maintenance Control by Costs

INDUSTRY has a major objective that has not changed for a long time—it is to make a better product at lower cost. Too few industrial plants have fully comprehended the extent to which expenditures for maintenance enter into product cost. This condition prevails because maintenance was relegated to the position of the stepchild of the melodrama—unwanted, but tolerated.

Good maintenance management means good cost control. Management insistence upon good cost control is likely to mean good maintenance organization and management. Without a knowledge of costs there cannot be measurement of the maintenance results. Without measurement there cannot be control.

Management Must Have Costs

Of costing details there are plenty, in connection with maintenance as with production. It is not the purpose to supply those details here, but rather to secure recognition of the need for costs in the interest of good management. The details must follow. They must fit the conditions of specific plants, and must be worked out by personnel familiar with the procedure of cost accounting and cost analysis.

The usual primary objective of keeping records of maintenance costs is to hold down expenditures. Perhaps that should not be so. It happens to be true that in some plants the primary objective *should* be to make certain that enough money is being spent on maintenance. There certainly must be a reckoning in any plant where only enough money is spent on maintenance to keep equipment and structures patched up.

Maintenance Objectives

Expressed more specifically, some of the major management aims of well organized maintenance procedure are these:

The determination of the optimum ratio of maintenance costs to plant income.

The measurement of maintenance performance, as a guide to betterment.

The allocation of maintenance costs in order to determine the desirable balance of expenditures for repair, prevention, and replacement.

W. C. Zinck, Head of Standards, North & Judd Manufacturing Company, in his series of articles, "Maintenance Cost Control," *Factory*, June, July, August, September, October, and November, 1933, well expresses the direct and byproduct aims of an effective maintenance cost control:

1. Prompt service rendered.
2. Good workmanship.
3. Each maintenance employee with a wholesome pride for prompt and economic service rendered by himself.
4. Best possible guidance on all major repairs.
5. Proper methods designed to designate the individual costs on each piece of equipment.
6. Guesswork taken out of charging time.
7. Maintenance costs compiled correctly.
8. Causes of exorbitant costs located and corrected.
9. Each foreman informed about costs in his department.
10. Total maintenance costs made available for comparison by management with preplanned costs.

He stipulates the following causes of maintenance inefficiency:

1. Poor or no supervision of operating force.
2. Poor physical arrangement of quarters.
3. The absence of adequate inspection routines and standards.
4. The absence of a suitable order routine for flagging expenditures before they are made.
5. Too many straw bosses.
6. Faulty organization, preventing an economic distribution of maintenance labor.

Further, he points out the need for serious consideration as to whether or not action shall be taken in regard to:

1. Reorganization of plans and methods.
2. Better or more mechanics.
3. Better or more lasting repairs.
4. More efficient preventive inspection.
5. Closer watch on costs of materials.
6. Closer concentration on production delays.

Carl G. Wyder, whose series in *Factory* was referred to in the preceding chapter, attests that in his own plant the following direct objectives were obtained:

Costs

1. Direct labor costs for each day, available the following day, for all labor in each division of the maintenance department, further subdivided to show (a) maintenance labor cost for each of 40-odd operating departments and (b) classification according to type of work (new or alterations, repairs or replacements, general maintenance).

2. Direct labor cost, and material cost, if desired, for each predetermined job, showing accumulated status to date, and final cost upon completion.

3. Monthly direct labor cost analysis.

Control

1. All new work, and all repair and maintenance work (except within narrow limits) subject to executive approval.

2. Progress of all work recorded and available for quick daily scrutiny and stimulation, eliminating lost orders and overlooked delays.

3. Completed orders fully certified by operating executives as well as by maintenance department.

"In addition to these outstanding results," says Mr. Wyder, "the innumerable byproduct possibilities that have been secured will be evident without discussion. They range from the development of dependable estimates before the initiation of work to an increased efficiency in the performance of the work itself, and conclude with such an array of authoritative records as to reveal, without speculation or difficult analysis, detailed information on machine performances and departmental trends, heretofore obscure and intangible. Of not less significance are the benefits accruing to the operating departments and derived through the centralization of control of maintenance effort, culminating in improved over-all efficiency."

Cost Control Methods

Three general methods of controlling maintenance costs are fairly well recognized. They are:

1. Control by ratio to production cost.

2. Control by budget.

3. Control by time allowance.

These three methods are well explained by examples of their application. In exercising control by ratio of maintenance cost to production cost:

Plant *A* sets a ratio for each productive department. This ratio is multiplied each morning by the productive hours the department will work that day to determine the department's allowance of non-productive time.

Plant *B*, manufacturing paper, establishes its ratio on the basis of performance for the preceding five years, and expresses it in terms of cost per unit of output. When this system was adopted, the ratio was set to effect a 15 per cent reduction in maintenance costs.

Plant *C* determines its ratio in relation to the cost of producing a ton of steel.

In control by budget:

Plant *D* prepares a yearly budget on a weekly basis. The week's figures are compared with weekly balance sheets. Increases or decreases of expenditures over budget are an important factor in determining the following year's budget. There is a penalty arrangement by layoff of employees for excessive time charged to simple repair jobs.

Plant *E* prepares an annual budget. Actual costs and budgeted costs are compared each month. An extraordinary expense not budgeted, but authorized, is charged off at the end of the year.

Plant *F* has a sliding budget. The amount allocated to each maintenance expense is plotted on a basis of departmental loading, starting from 30 per cent capacity. As the volume of business fluctuates, factory instructions are issued to operate at a specific capacity basis. The executives affected are given 60 days to make necessary adjustments.

Control by time allowance is the method in use in the following cases:

Plant *G* pays the worker on his point-hour record for the day. The rate is established by time-study.

Plant *H* pays a bonus of half of the time saved. Rates are set by time-study or comparison. Application is to electrical repair work only in this case.

Plant *I* pays the workers as a bonus a percentage of the time saved over estimated time. For easily estimated jobs, the worker gets 50 per cent of the saving; on jobs difficult to estimate, 33⅓ per cent.

CHAPTER FIVE

Maintenance on Incentive

THERE is an undeniable relationship among control, budgeting, costing, and incentives. Effective use of any of these tools of management depends upon the cooperative effort of the maintenance personnel.

Except for the objective of holding his job, what urge is there for the maintenance worker to assist in the control of expenditures, meeting or beating the budget, posting accurate costs? None. He knows that he is working on this or that. He probably feels that he is giving an honest day's work—and maybe a little more—for the pay he is getting. But he does not see the picture as a whole. There is every reason to give him a specific thing to shoot at. The most effective target is additional money in the pay envelope.

Too many management executives, when they think of maintenance on incentive, visualize the time study of occasional jobs, and immediately throw up their hands.

Incentive payment has been set on such jobs. Time study has been instrumental in determining the rates. Such procedure has been successful principally in large plants, which have well-trained time-study departments accustomed to breaking down jobs into their elementary components and to reassembling those components into allowances for other jobs. A skilled time-study and estimating department can become remarkably proficient in setting rates for maintenance work, the estimated times showing little variation from actual times, and the above and below errors balancing each other.

Example of Maintenance Incentive

Maintenance painting is one of the jobs on which incentives have been successfully set by means of time study and job analysis. Figure 15 shows the time allowance chart used by the Westinghouse Electric and Manufacturing Company in setting its incentive rates for paint-

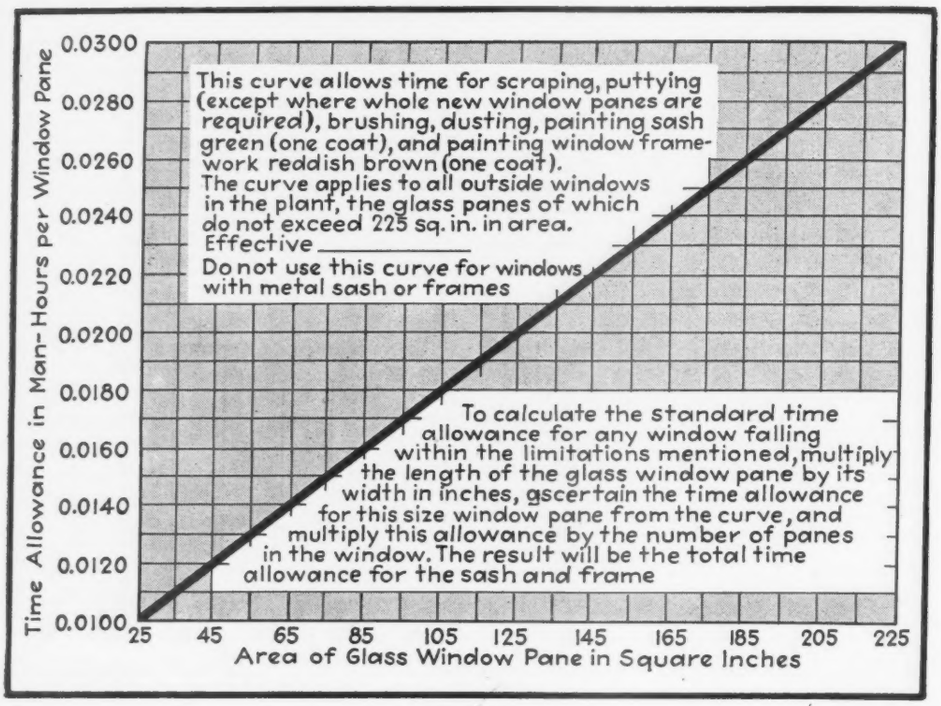

Time Allowance in Man-Hours per Window Pane
0.0300
0.0280
0.0260
0.0240
0.0220
0.0200
0.0180
0.0160
0.0140
0.0120
0.0100
This curve allows time for scraping, puttying (except where whole new window panes are required), brushing, dusting, painting sash green (one coat), and painting window framework reddish brown (one coat).
The curve applies to all outside windows in the plant, the glass panes of which do not exceed 225 sq. in. in area.
Effective
Do not use this curve for windows with metal sash or frames
To calculate the standard time allowance for any window falling within the limitations mentioned, multiply the length of the glass window pane by its width in inches, ascertain the time allowance for this size window pane from the curve, and multiply this allowance by the number of panes in the window. The result will be the total time allowance for the sash and frame
25 45 65 85 105 125 145 165 185 205 225
Area of Glass Window Pane in Square Inches

Figure 15

ing windows. Figure 16 shows the same company's standard time data for painting pipes. Figure 17 shows this company's estimate of a specific painting job.

However, time records without time study will serve for the average plant just beginning the organized management of maintenance. A practical man, who has himself been through the mill, can go a long way in setting times. If the correct rates are then determined, so that the worker can earn more than he has been accustomed to receive, and so that the company will have less total maintenance expenditure for a given amount of work, the simple incentive system is functioning.

Going the Limit

The Corning Glass Works has carried this method rather far. I quote Alfred Vaksdal, plant engineer:

"To be a success, an incentive system must assume at the beginning that 'all men are created equal.' Given the opportunity, the superior man will quickly forge to the front, and he should be given that opportunity.

"The first step in establishing an incentive plan that will meet the requirements is to make a study of the work of each department and prepare a chart for each foreman to show his duties and the items for which he is held responsible. The purpose is to describe each department graphically on a single sheet. For example, charts of the electric and pipe shops are made to indicate in general all work covered by the foremen in these shops. The first line of the chart shows what will be expected of the foreman. This arrangement is followed in the chart for every foreman and every individual job. Maintenance, repair, and construction are separated because these items are handled differently from an accounting standpoint. The separate services of the shop are then listed, followed by the larger subdivisions of such services. Thus we have a picture of the foreman's job.

"Each large subdivision of the chart is then charted separately and subdivided until a detailed graph of each service is obtained, showing what enters into that service and the responsibilities of the shop in connection with the service, such as inspection, meter reading, charts to be changed, periodic cleaning and testing, and any established routine necessary for satisfactory performance.

"The full set of charts gives a complete, detailed picture of the functions of the department in ques-

Figure 16

Inside Diameter of Pipe	Outside Diameter of Pipe	Periphery of Pipe in Inches	No. of Sq. Inches per Foot of Pipe	No. of Sq. Feet per Foot of Pipe	Value per Lineal Ft. 1st Coat	Value per Lineal Ft. 2nd Coat
¾"	1.05	3.30	39.6	0.28	0.0025	0.0023
1"	1.32	4.17	50.0	0.35	0.0032	0.0029
1¼"	1.66	5.22	63.0	0.44	0.0040	0.0036
1½"	1.90	5.97	72.0	0.50	0.0045	0.0041
2"	2.375	7.46	89.5	0.62	0.0056	0.0050
2½"	2.875	9.00	108.0	0.75	0.0068	0.0061
3"	3.50	11.00	132.0	0.92	0.0083	0.0075
3½"	4.00	12.57	151.0	1.05	0.0095	0.0085
4"	4.50	14.14	169.7	1.18	0.0106	0.0096
4½"	5.00	15.71	188.5	1.31	0.0118	0.0106
5"	5.56	17.47	209.6	1.45	0.0131	0.0117
6"	6.625	20.81	249.7	1.73	0.0156	0.0140
7"	7.625	23.95	287.4	2.00	0.0180	0.0162
8"	8.625	27.10	325.2	2.26	0.0203	0.0183
9"	9.625	30.24	362.9	2.52	0.0227	0.0204
10"	10.75	33.77	405.2	2.82	0.0254	0.0228
11"	11.75	36.91	442.9	3.07	0.0276	0.0249
12"	12.75	40.00	480.0	3.33	0.0300	0.0270
	13.00	40.84	491.0	3.41	0.0307	0.0276
	14.00	43.98	527.8	3.66	0.0329	0.0296
	15.00	47.12	565.4	3.93	0.0354	0.0318
	16.00	50.27	603.2	4.19	0.0377	0.0339
	17.00	53.41	640.9	4.45	0.0400	0.0360
	18.00	56.55	678.6	4.71	0.0424	0.0382
	19.00	59.69	716.3	4.97	0.0447	0.0403
	20.00	62.83	754.0	5.24	0.0472	0.0424
	21.00	65.97	791.6	5.50	0.0495	0.0446
	22.00	69.12	829.4	5.76	0.0518	0.0467
	23.00	72.26	867.1	6.02	0.0542	0.0488
	24.00	75.40	904.8	6.28	0.0565	0.0509
	25.00	78.54	942.5	6.55	0.0590	0.0531
	26.00	81.68	980.2	6.81	0.0613	0.0552
	27.00	84.82	1017.8	7.07	0.0636	0.0573
	28.00	87.96	1055.5	7.33	0.0660	0.0594
	29.00	91.11	1093.3	7.59	0.0683	0.0615
	30.00	94.25	1131.0	7.85	0.0707	0.0636

STANDARD TIME — Routing No.

Dwg. Title	Sec. L-13	Style Pattern		Dwg. No.	Sub.
Part Sec. M.C. Lot 1 to 17		Ins. Spec.		Item	
Mtl. Size	Pcs. per 100 lb.	Die Mold		L. Space	Sub.
Mach. Tool and No.		Spec. Tool or Fixture		STANDARD TIME Set-up	STANDARD TIME Each Piece
Operation Spray & hand paint		Oprn. No. / Class of Labor / How Set			1140.00

Spray and paint end wall	45.00
" " " Bay No. 1	41.00
No. 2-3-11-12	200.00
No. 4-5-6-7-8-9-10-13-14-15-16	561.00
No. 17	90.00
	943.00
Get material to job and set up scaffold	110.00
Group Leader	30.00
	1083.00
Spray and paint 18 columns from 1st to 2nd floor	30.00
" " " storeroom partitions & other partitions	15.00
	1128.00
Time taken 1020.88 hours	
111.7%	

Recorded-Time Clerk | Cost Clerk | Date | Signed | Time Study Dept.

Figure 17

tion. Knowing these functions the foreman can assign definite duties to each man in his shop. For example, one man may be made responsible for all the items of fire protection. Every order for repairs or maintenance of the system goes to him. He has the responsibility of keeping the entire system in first-class shape, and when anything is wrong the foreman knows whom to hold accountable.

"If one chart does not carry with it sufficient work to keep a man occupied, the duties outlined on additional charts may be assigned to him. From the charts, responsibility for every detail for which the shop is accountable can be allotted, and each man becomes an individual unit on his own.

Incentives, Too

"The second purpose of the charts now can be realized, namely, to add a financial incentive for the individual for efficient and satisfactory performance of duty.

"The number of hours or the total cost of performing the duties outlined in each chart or subdivision can be determined or estimated for a period of time and an operating budget can be set up. This allowance is made known to the man who is responsible for that subdivision. If the actual cost of doing the work falls below the budget, he is paid one-half of the saving and the company receives the other half.

"From an accounting standpoint the system is simplicity itself. Each subdivision is given an order number. All labor and material are charged to that order. A budget or cost estimate is set for the order. At the end of any period the cost is subtracted from the budget figure and one-half the difference is paid to the man."

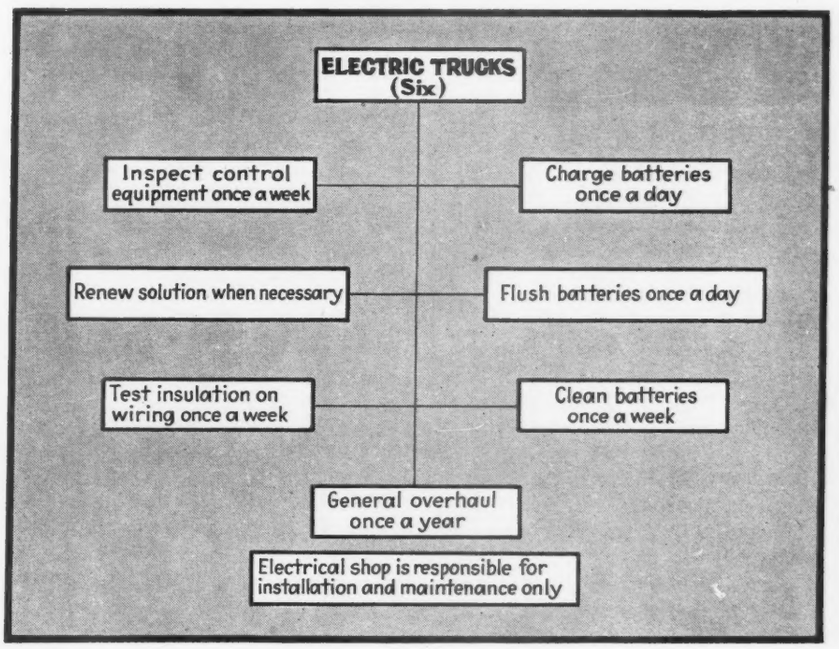
Two of the simpler charts are shown by Figures 18 and 19. Among similar charts prepared were those dealing with the pipe shop, compressed air system, fuel oil system, live steam system, electrical department, lighting system, fire alarm and auto call, telephone system, elevators, generators, transformers, power lines, fuses, branch lines, control equipment, and special systems.

Now Know Everyone's Job

"The direct advantages from charting our maintenance work were rather startling," according to Mr. Vaksdal. "When the plant engineering department decided to prepare the charts, it was found that no one knew except in a general way what the work of each shop covered. The foreman was called in, and the same difficulty was encountered again. Hence it became necessary for both parties to work together in preparing the charts. This close contact gave the foremen and the engineering department a new viewpoint on the shops. Both learned.

"In several cases overlapping duties were found. For example, we had to decide who should inspect the sprinkler systems—the pipe shop or the safety inspector. In the case of motors the question arose as to whether the oiling belonged to the millwrights, who oiled the reduction gears and machines driven by the motors, or to the electric shop which inspected the motors. Should the electric shop or the pipe shop attend to the alarms on the dry-pipe valves? These and many other questions were brought out. Some items were found to be receiving double or triple inspection or maintenance service, whereas others had none.

Figure 18


ELECTRIC TRUCKS (Six)
Inspect control equipment once a week
Charge batteries once a day
Renew solution when necessary
Flush batteries once a day
Test insulation on wiring once a week
Clean batteries once a week
General overhaul once a year
Electrical shop is responsible for installation and maintenance only

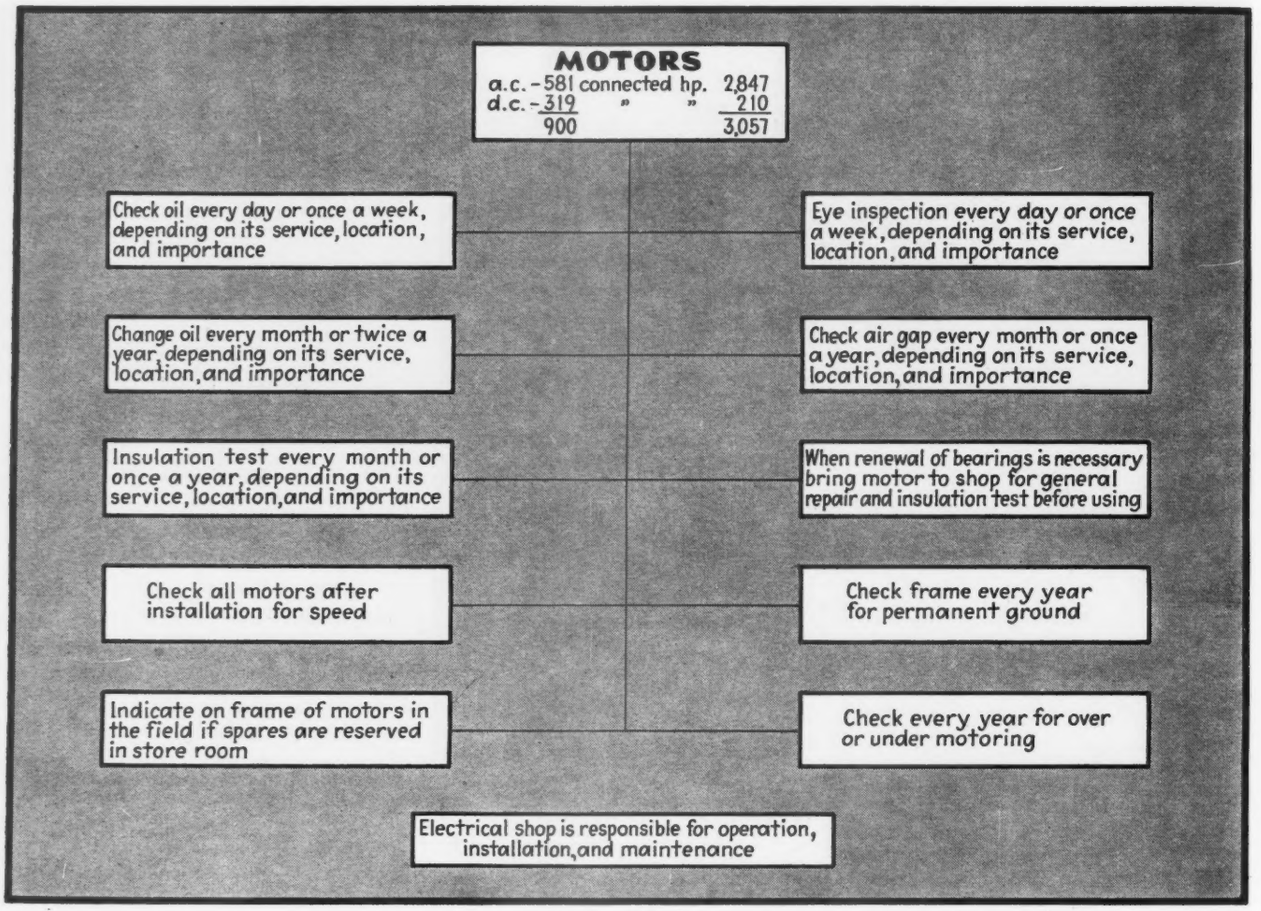

MOTORS
a.c. - 581 connected hp. 2,847
d.c. - 319 " " 210
900 3,057
Check oil every day or once a week, depending on its service, location, and importance
Eye inspection every day or once a week, depending on its service, location, and importance
Change oil every month or twice a year, depending on its service, location, and importance
Check air gap every month or once a year, depending on its service, location, and importance
Insulation test every month or once a year, depending on its service, location, and importance
When renewal of bearings is necessary bring motor to shop for general repair and insulation test before using
Check all motors after installation for speed
Check frame every year for permanent ground
Indicate on frame of motors in the field if spares are reserved in store room
Check every year for over or under motoring
Electrical shop is responsible for operation, installation, and maintenance

Figure 19

"The engineering department discovered instances where a little study would result in sizable savings.

"Millwright charts will in time show where the bulk of the repairs occur, what machines are obsolete or overloaded, and where mistakes in design have been made. Watchmen charts will show the fire protection controls, the stations, the areas covered, and the location of fire protection equipment, such as extinguishers and axes.

"When finally installed complete, the system will provide every man in the shop with definite responsibilities and an incentive to shoulder those responsibilities and keep up his end. Each man will have a picture that will show just the duties assigned to him. The foreman will have a picture of his entire shop and the items he must watch and supervise, and the plant engineering department will have detailed graphically the entire plant and the extent of all maintenance work."

Incentives for maintenance is a topic about which much will be heard. Most of what is to come in the future will be recounting of the details of incentive applications. After all, the determination of incentive times and methods of payment is largely a matter of the application of common sense. The principal job for management to do right now is to convince itself that it has sufficient incentive to establish maintenance incentives.

CHAPTER SIX

Yardsticks for Maintenance

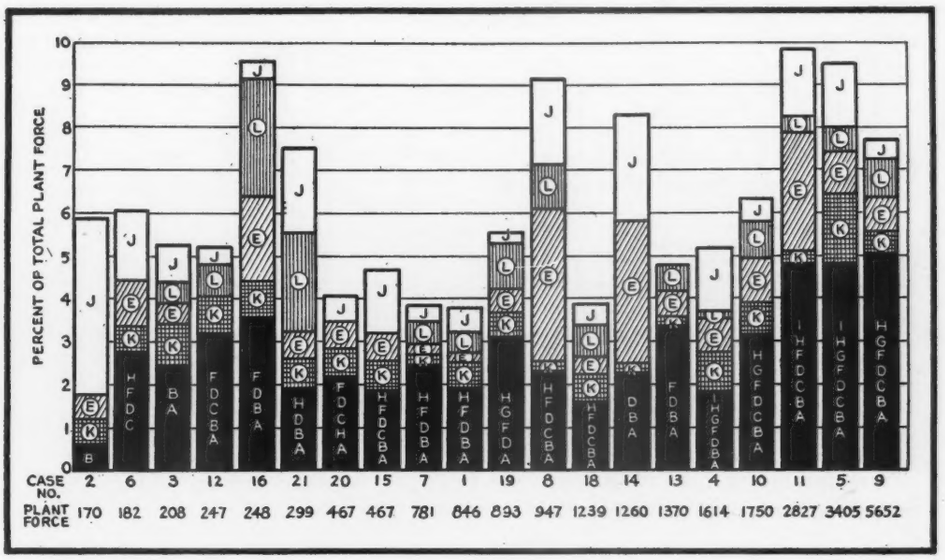
IN measuring maintenance the objective is to determine: (1) Whether or not results are consistent with the money being spent; (2) whether or not just the right amount of money is being spent.

For the plant starting from scratch the best procedure is to make some kind of approximation as a basis to work from, then to introduce refinements. In the long run, accurate measurement must depend largely upon the budgets set, the cost records kept, and the use that is made of the cost figures.

Company policy also is an influencing factor. For example, is equipment to be loaded as close as possible to maximum, in order to get the most production before obsolescence sets in? To what extent is maintenance to be preventive? To what extent merely repair?

Too much nursing of equipment, to prolong its life, risks eventual junking of equipment that is still in physical condition to produce to the established standards, yet has been superseded in design to the point where it is no longer useful.

Figure 20



A—Supervision and Clerical
B—Belt Repairmen, Oilers, Millwrights
C—Blacksmiths and Welders
D—Electricians
E—Machinists, Machine Repairmen
F—Carpenters, Pattern Makers
G—Painters
H—Masons, Plumbers, Tinsmiths
I—Truck Repairmen
J—Janitors, Sweepers, Porters, Etc.
K—Watchmen
L—Yardmen

Too little preventive maintenance endangers production continuity. A breakdown of vital equipment may cost many times the maintenance expenditures that would have prevented it.

Let us look first at an approximation or two dealing with the number of maintenance employees.

There is shown in Figure 20 a comparison of the maintenance forces to total plant forces in 20 manufacturing plants. The data were made available by E. V. Stoody and G. I. Ross, of MacDonald Brothers, Inc., of Boston. They are selected from similar data collected from a large number of plants.

Chief significance of these data is their lack of uniformity. That is to be expected in a cross-section of plants engaged in manufacturing many kinds of products. However, since we are approximating only, the chart will serve our purpose.

Note that, regardless of the number of employees, kind of product, and age of plant, the variation in proportion of maintenance to total plant employees lies between 4 and 10 per cent. Note, also, that this variation is greatly influenced by the number of janitors, sweepers, watchmen, and yardmen.

This factual chart can be used in this way: Pick out the data on the plant that has a total force closest to yours. Compare the number of your employees in the various classifications to the numbers in the same classifications shown on the chart. Compare the chart ratio of maintenance to total employees with the ratio in your plant. Figure out the why's for the differences.

A quite different method of measuring maintenance involves the use of a formula, and employs costs as the measuring unit. This formula was devised by C. J. Stuart, Industrial Engineer, of New Haven, is based on experience records, and has been checked to his satisfaction in 24 plants with from 150 to 5,000 employees, making products as varied as chemicals, footwear, clothing, tires, mechanical rubber goods, small metal articles, and textiles.

This is the formula:

$$m = \left(\frac{a}{684} + \frac{b}{889} + \frac{c}{605}\right) d$$

Where a = square feet of floor space in active use
b = pounds of finished goods produced in month
c = replacement value in dollars of all machines and equipment in active plant account
d = average hourly pay rate, in dollars, of all maintenance workmen
m = monthly cost of maintenance labor, in dollars

Mr. Stuart's explanation of the derivation of his formula follows:

"Part one of the formula is based on the labor hours consumed in maintaining buildings, sprinkler systems, heating systems, and lighting systems, taking into account the square feet of floor space in active use. The total hours of labor per month on this class of work divided by the total active square feet of floor space equals 'hours per square foot.' The result from my data is

$$0.00146 +, \text{ or } \frac{1}{684}$$

"Part two is based on the labor hours consumed in maintenance work that fluctuated nearly in proportion to the amount of product turned out. I secured a fraction representing 'hours per pound of product,' by dividing the total hours involved by the pounds of product finished. The result is

$$0.001124 +, \text{ or } \frac{1}{889}$$

"Part three furnishes the 'hours per dollar of replacement value of equipment,' and was found by dividing the total hours involved (total maintenance hours minus hours allocated in parts one and two of the formula) by the total replacement value of machinery and equipment in the active plant account. The result is

$$0.001653 —, \text{ or } \frac{1}{605}"$$

Remember that these methods of making approximations are offered for purposes of rough inspection only. They are not intended as master gages. The final result will depend upon how much common sense is used in organizing for maintenance, in managing the department after it is organized, in keeping cost records, and in analyzing those records.

CHAPTER SEVEN

Equipment, Tools, Supplies

EVEN though a maintenance department be highly organized and well managed, it lacks the opportunity for effective operation, and therefore worth-while contribution to low-cost production unless its equipment and tools are of the kind and quantity to permit prompt and economical service. With maintenance as with production, operation can be no more effective than its equipment permits.

For example, there was the plant whose entire production was held up because the maintenance department lacked a tool suitable for the job of making holes for foundation bolts in concrete. Layout had been changed; much equipment had to be moved. Drilling was started with an obsolete tool, but the production delay that ensued was so serious that one of the new electrically operated hammers was substituted. Holes per hour increased five-fold, rearrangement of equipment was completed speedily, production was resumed with little additional loss.

In another plant, unsatisfactory lighting was holding back production, causing many rejects. A few dollars spent for one of the relatively new photronic cell foot-candle meters enabled quick determination of lighting requirements. New fixtures were installed at the proper locations. Production immediately went up to where it should have been.

Pick Your Own Examples

There is no plant that cannot cite instances of similar losses because the maintenance department was inadequately equipped. Included would be cases like these:

Motor failures with consequent production delays that could have been prevented by the use of simple insulation resistance testers.

Wasted power, with its contribution to high production costs, because of lack of suitable instruments and meters to determine power consumption and losses. Compact testing outfits, containing all necessary instruments, shunts and switches, permanently connected, are available.

Wasted time for production and for maintenance as well, for lack of shop service trucks, equipped with complete sets of tools and supplies.

Unnecessary lost time and expense because welding equipment was not available in emergency.

Wasted man hours and machine hours because there were lacking such portable tools as electric drills and grinders; power-driven hand saws; spray-painting equipment; electric hammers; floor-scrapers.

For the most part such equipment as has been referred to is for on-the-job service. This is a class of equipment that is especially needed to prevent production delays.

Don't "Unload" on Maintenance

There is also the in-the-shop class of equipment to be considered. "Oh, send that to the maintenance shop," is an offhand disposition of equipment too frequently made.

Almost every plant of size must have its machine shop. Granted that the greater part of replacement parts for machinery will be bought from the makers of those machines, still there will be emergency occasions when parts must be made to tolerances that are not obtainable on any but strictly first-class machine tools.

And, of course, there is the plant that really can afford to make its own replacement parts for much of its equipment. To say nothing of the plant that has to make its own special brackets, braces, and similar parts for the installation of motors and handling equipment.

This brings up the matter of measuring tools. It is not enough to have machines to produce accurate work. The workman must know that the accuracy has been obtained. Calipers, micrometers, gages of various kinds, and at times instruments are essential.

The same reasoning indicates that the carpenter shop, tin shop, welding shop, electrical shop, and pipe shop must be furnished with the proper equipment and tools unless waste of man time and production time is to occur.

And accessories. There is nothing more aggravating—as a matter of fact, time consuming—than the time-honored search for lathe dogs, machine clamps, angle plates, bolts and nuts, mandrels, arbors, and the like. These accessories are so inexpensive that scarcity is inexcusable.

Hand tools, too, are important. The average mechanic takes pride in his tools and will make sacrifices that he may have a good set. But should the responsibility be his? Here, again, is a question of policy. Which hand tools should the worker furnish? Which ones should be furnished by the company?

If the worker furnishes his own tools, he *will* look after them. If the company furnishes the tools, the worker *must* look after them. Obviously a check and stores system is required if the company is to furnish the tools. How extensive and expensive can it be? What median policy will produce the best results so far as efficiency and cost conservation are concerned? If the worker furnishes tools, what is the company obligation to furnish lockers for their safe keeping? What shall be the system of in-and-out check-ups of the worker's personal property when he is hired and when he leaves?

It is difficult for the average executive to become warmed up about maintenance tools. They are such ordinary things.

Let Maintenance Function

Perhaps a little more imagination is needed. A drop or two of oil has saved many a dollar, kept many a delivery date for the plant that purchased it. Yet that oil was not applied to the place where it did its job without the use of an oil can. A beam is a beam, whether 4 feet long or 4 feet 2. But it makes nobody money if it happens to be 4 feet 2 when it should be 4 feet and there is no hacksaw blade at hand.

A 10-horse motor will carry a 5-horse load. But what's the use of operating a motor at low efficiency and power factor? A wattmeter will prevent such losses.

Brooms may be brooms, but some sweep faster than others and last longer.

Any number of square feet may be painted with a 4-in. brush, if time enough is taken. If time is worth anything, a 6-in. brush is better.

A 10-in. stillson may finally get a rusty joint open. But what would a 16-in. have done?

This could go on. But perhaps enough has been written to show what is meant by using imagination in regard to maintenance tools. They *are* important. They afford a link in the plant operation chain that can be weak or strong.

PRODUCTION IS INCREASED WITH DAYTON COG-BELT DRIVES

COMPACT ★ DURABLE ★ EFFICIENT

● Men turn out more work—better work, too—in plants equipped with Dayton Cog-Belt Drives. This is due to the uninterrupted efficiency of both men and machines.

When Dayton Drives replace old-fashioned drives, the plant is brighter, quieter, pleasanter. Walls and ceilings stay cleaner and men see better and work faster. Distracting noise is eliminated. In addition, Dayton Drives permit machines to be more compactly and conveniently arranged. Working conditions are more favorable, therefore, to maximum production.

But that isn't all. Output is increased by Dayton Drives because machines perform better and require less frequent adjustment. These drives don't slip, so machine speed is maintained. They don't fly off the pulleys and interrupt operation. And because less belt tension is needed, bearings last longer and machines aren't held up so often for repairs.

And the long life of Dayton Cog-Belts is due to their patented, laminated, die-cut construction. They are "built-to-bend"... to grip the pulleys ... to provide positive traction on short centers.

● The only V-Belt "Built-to-Bend." See how the "cogs" take up the compression on the inner surface. This unusual lengthwise flexibility is combined with extreme crosswise rigidity which prevents squashing, twisting, and weaving.

Being accurately die-cut, they snugly fit the grooves of all standard pulleys. Their crosswise rigidity prevents squashing, twisting and weaving. They run smoothly and powerfully.

Use Dayton Cog-Belts for trouble-free, economical service. When modernizing your plant or installing new machinery, equip for Dayton Cog-Belt Drives. There's a stock near you. Full information and descriptive literature will be gladly sent to you upon request.

THE DAYTON RUBBER MANUFACTURING CO., DAYTON, OHIO

World's Largest Manufacturers of V-Belts—Manufacturers also of Dayton Fan Belts, Dayton Red Tube Radiator Hose, and the Famous Dayton Thorobred Tires and Tubes

SPECIFY

Dayton

COG-BELT DRIVES

COG-BELT DRIVES—F. H. P. V-BELT DRIVES—V-FLAT DRIVES—COMPLETE DRIVES, PULLEYS, AND BELTS IN STOCK, FRACTIONAL TO 100 H. P.

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Breckwoldt Toilet Seat; liquid celluloid finish applied with DeVilbiss Equipment

Long and successful use by leading manufacturers—that is real assurance of the efficiency and reliability of DeVilbiss Spray-Finishing Equipment. DeVilbiss Equipment is effective not only in applying finishes of a higher quality, but also in increasing the efficiency of your finishing department and in reducing costs.

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TRADE LITERATURE

ABRASIVE CLEANING—Data Book No. 111, on airless abrasive cleaning by means of the Wheelabrator. — American Foundry Equipment Co., Mishawaka, Ind.

BEARINGS—Folder, title "Super-Precision Ball Bearings for Spindles."—The Fafnir Bearing Co., New Britain, Conn.

BELTING—Bulletin No. 6808-B, on Condor Compensated belt.—The Manhattan Rubber Mfg. Division of Raybestos-Manhattan, Inc., Passaic, N. J.

BELTING—Folder, on Tannate leather belting and belt preserver.—J. E. Rhoads & Sons, 35 North 6th St., Philadelphia.

CARBON MONOXIDE INDICATOR—Bulletin No. DS-1, describing carbon monoxide indicator.—Mine Safety Appliances Co., Braddock, Thomas, and Meade Sts., Pittsburgh.

COMPRESSORS—Two bulletins: L-611-B4A, on single horizontal, single-stage, steam- and motor-driven compressors with 11- and 13-in. stroke; L-611-B5A, on same with 5-, 7-, and 9-in. stroke.—Worthington Pump and Machinery Corp., Harrison, N. J.

CONTACTORS—Folder No. 1140, on Type LTZ contactors for a.c. service.—The Electric Controller & Mfg. Co., Cleveland, Ohio.

DRAWN STEEL — Folder, on advantages and uses of cold drawn steel.—Union Drawn Steel Co., Massillon, Ohio.

DRIVES—Bulletin No. 1259, on Texrope belts and sheaves for machine tools.—Allis-Chalmers Mfg. Co., Milwaukee.

ELECTRIC CABLE—Booklet, title "Taking Boulder Dam to Market."—General Cable Corp., 420 Lexington Ave., New York.

ELECTRIC FURNACES—Leaflet TE 20, describing pot- and trough-type electric furnaces.—Harold E. Trent Co., 618-640 North 54th St., Philadelphia.

ELECTRIC HEATING UNITS—Leaflet TC 30, on electric heating elements and units.—Harold E. Trent Co., 618-640 North 54th St., Philadelphia.

ELECTRIC TOOLS—Catalog No. 36, on line of electric tools.—Skilsaw, Inc., 3310-20 Elston Ave., Chicago.

ELECTRIC TOOLS—Two bulletins: No. 899, on universal electric tools; SP-1876, on "Power Vane" rotary tools.—Chicago Pneumatic Tool Co., 6 East 44th St., New York.

EXPANSION BOLT—Bulletin U-401, describing Rawl-Drive expansion bolt.—The Rawlplug Co., Inc., 98 Lafayette St., New York.

FLOORING MATERIAL—Folder RW532, describing Ruggedwear Resurfacer.—Flexrock Co., 800 North Delaware Ave., Philadelphia.

FRICTION MATERIALS—Brochure FM-4A, on styles and selection of friction materials.—Johns-Manville, 22 East 40th St., New York.

GRINDERS—Bulletin No. 42, describing line of bench and pedestal grinders.—Baldor Electric Co., 4357 Duncan Ave., St. Louis.

GRINDING MACHINES—Folders showing 10 models of grinding and lapping machines.—Norton Co., Worcester, Mass.

HARD RUBBER LININGS—Catalog No. 300-1, title "Ace Hard Rubber Protection for Chemical Process Industries."—American Hard Rubber Co., 11 Mercer St., New York.

HYDROMETER — Folder, announcing the Pacometer, an automatic, compensating hydrometer for control of boiler salines.—The Permutit Co., 330 West 42d St., New York.

ILLUMINATION METER — Folder letter, announcing Sight Light Indicator.—The Sight Light Corp., 342 Madison Ave., New York.

LATHE—Catalog, describing 9-in. "Workshop" precision lathe and attachments.—South Bend Lathe Works, South Bend, Ind.

LUBRICATING OIL—Summary report of lubrication tests made on alloy bearings

He could pass with deadly accuracy *but*... He wasn't "ALL AMERICAN"

BECAUSE proficiency in one phase of attack does not make a world's champion back. To be an "All American", he must excel in running the ball, passing, blocking and be adept on defense. Then critics will proclaim him "one of the best" in the land.

As athletic experts demand all around ability from their players, so Industrial Engineers demand all around performance from transmission belt.

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An industrial "ALL AMERICAN"

Designed along well defined engineering principles, Monobelt meets the demands of modern high speed drives and modern productive units. Its wide range of adaptability, combined with its capacity to withstand the strain of shock loads, to deliver maximum traction at lower per unit cost, and to continue to transmit power uninterrupted for a longer period of time, definitely certifies Monobelt an Industrial "All American".

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Alexander Brothers INC.

PHILADELPHIA PENNSYLVANIA

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Gypsteel Plank* Saved Time and Money on This Roof Deck

CONTRACTOR TELLS WHY

ESTABLISHED 1894

P. J. CANTWELL & SON
CONTRACTORS AND BUILDERS
82 DWINNELL STREET

WEST ROXBURY, MASS., March 11, 1935.

Structural Gypsum Division
American Cyanamid & Chemical Corporation
30 Rockefeller Plaza
New York, N. Y.

Attention of Mr. A. C. Waghorne

Dear Sir:

Now that we have finished erecting the 60,000 feet of gypsum plank which you furnished us for the roof of the Storage Shed, at Natick, Massachusetts, we would like to take this opportunity of letting you know what we think of the plank.

In the first place, this work was being done under severe winter conditions, which of course would have made the cost of a concrete roof prohibitive. We found Gypsteel Plank very easy to handle and erect - in fact our erection cost was no more than it would have been had we used a wood plank roof with spiking pieces.

All of the comments which we have heard relative to the appearance of the plank from the inside are very favorable. Although the specifications require it to be painted, we feel that for many installations an unpainted job would be very satisfactory.

In the future we are hoping to make further use of "Gypsteel Plank".

Very truly yours,
P. J. Cantwell & Son.
By B. A. Cantwell

Erecting PLANK on the Artillery Transportation Storage Shed, the Armory Commission, Commonwealth of Massachusetts, J. Theodore Whitney, Engineer. On this job a wood roof was the base specification; PLANK was an alternate. But because the difference in cost was so small, PLANK was selected.

GYPSTEEL PLANK

U. S. Pat. No. 1,854,396
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Other U. S. and Foreign Patents Pending

**The term PLANK as applied to cementitious building products is a registered trade-mark of the American Cyanamid & Chemical Corporation.*

STRUCTURAL GYPSUM DIVISION
American Cyanamid & Chemical Corporation
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MORE and more industry is discovering that GYPSTEEL PLANK is the ideal material for fast, winter construction. It offers practical advantages for fire-safe roofs and floors in low cost installation, speed of erection, strength and weather resistance. The rise in sales (more than 800% in four years) proves conclusively that PLANK fills a definite need in the building industry today. Send for bulletin.

while using Pyroilized oil. — Pyroil Co., Dept. C-CFM, La Crosse, Wis.

MATERIAL—Booklet, telling the story of the diatom from which Celite is made; also section telling of services performed by Celite.—Johns-Manville, 22 East 40th St., New York.

MEASURING INSTRUMENTS—Catalog, on line of measuring instruments and gages; folder, describing Model 110 Comparator.—Federal Products Corp., 1144 Eddy St., Providence, R. I.

METAL HOSE—Booklet, on flexible metal hose and fittings.—Atlantic Metal Hose Co. Inc., 123 West 64th St., New York.

MOTORS—Bulletin GEA-246D, describing "7500 Series" high speed synchronous motors.—General Electric Co., Schenectady, N. Y.

PIPE—Booklet, describing pipe and tubing.—Republic Steel Co., Cleveland.

PNEUMATIC EQUIPMENT—Folder, on pneumatic-tired wheels and pneumatic casters.—Saginaw Stamping & Tool Co., Saginaw, Mich.

PUMPS—Bulletin 157, on centrifugal pumps.—Morris Machine Works, Baldwinsville, N. Y.

PUMPS—Bulletin R-200, on Rotex pumps.—Quimby Pump Co., Inc., 363 Thomas St., Newark, N. J.

PUMPS—Bulletin W-102-B1, on Type TB horizontal duplex piston pumps.—Worthington Pump and Machinery Corp., Harrison, N. J.

PUMPS—Two bulletins: W-321-B7, on open-impeller centrifugal pumps; W-450-B-24, on deep-well turbine pumps.—Worthington Pump and Machinery Corp., Harrison, N. J.

PURCHASE PLAN—Bulletin WP-1088, announcing term-payment purchase plan which takes advantage of FHA-insured loans.—Worthington Pump and Machinery Corp., Harrison, N. J.

RAILINGS—Folder, on welded, jointless-post, steel railings.—The Fabricated Steel Products Co., Wheeling, W. Va.

RECORDING INSTRUMENTS—Bulletin No. 735, on graphic kva. meter; form No. 1308, on all types of recording instruments.—The Esterline-Angus Co., Indianapolis.

REFRACTORY CEMENT—Booklet, title "Fire Tamers," recounting research on refractory cements.—Johns-Manville, 22 East 40th St., New York.

RELAY—Bulletin GEA-2209, describing Type TB-2 bearing-temperature relay for protecting machine bearings against abnormal heating.—General Electric Co., Schenectady, N. Y.

ROOFS—Booklet, on built-up roofs.—Bird & Son, Inc., East Walpole, Mass.

ROOFS—Booklet, title "Facts about Built-Up Roofs."—Johns-Manville, 22 E. 40th St., New York.

SCREWS AND BOLTS—Catalog, on line of screws, bolts, and nuts.—Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago.

SHEARS—Catalog S, on line of shears.—The Cincinnati Shaper Co., Cincinnati.

SHEET STEEL—Folders 333 and 334, on Beth-Cu-Loy rust-resisting steel sheets.—Bethlehem Steel Co., Bethlehem, Pa.

SOCKET SCREWS—Bulletin No. 832, describing Bristo socket setscrews and socket head capscrews.—The Bristol Co., Waterbury, Conn.

SOLVENTS—Booklet, on coal tar solvents.—The Neville Co., Neville Island Post Office, Pittsburgh.

SPEED CONTROL—Booklet No. T-7025, on variable speed control for machine tools.—Reeves Pulley Co., Columbus, Ind.

TUBE FABRICATION—Bulletin No. 40, on equipment for fabricating and shaping tubing.—Parker Appliance Co., Cleveland.

UNIT HEATER—Booklet, announcing Floor-flo heater.—The Trane Co., La Crosse, Wis.

GIANTS OF TRANSPORTATION

Today's ocean liners demonstrate both the economy and the necessity of transporting many more passengers and much more *freight* than ever before, at each trip. • Management in industry must apply the same principle to its own load-transportation. With costs climbing steadily, the needless picking up and putting down of plant and warehouse loads *is a profit-killing waste that must be stopped.*

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Whatever your product or your volume, you need and must have the most modern methods of transporting your materials *safely;* in greatest *quantity;* for the longest *distance;* in the least *time* and *at the lowest cost.*

Elwell-Parker builds Power Industrial Trucks in so *complete* a line that your own need for lowest-cost handling can be met exactly, through the right type and size of Power Truck, Tractor or Crane.

The best Elwell-Parker for *your* work will be chosen because of its ability to handle record loads with speed and safety, and to reduce costs so sharply as to pay for itself within a year—or even a few months.

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Executives should read "This New Industrial Pick-up." Free, if requested on your business stationery. The Elwell-Parker Electric Company, 4323 St. Clair Avenue, Cleveland, Ohio.

Members of a fleet of Elwell-Parker Trucks serving S. S. "Normandie" at the French Line docks, New York.

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ESTABLISHED 1893 • BUILDING POWER INDUSTRIAL TRUCKS SINCE 1906

SHORTEN the INTERVAL
between
Raw Materials
and
Finished Product
and
YOU INCREASE PROFITS

• *TIME* — the manufacturing interval between raw materials and finished product — is costly. In many plants it's *far too costly.* The time men wait for work, the machines are idle, are hidden costs that often seriously increase production cost.

• LAMSON CONVEYORS speed the manufacturing process—and thus hasten delivery of finished products, increase capital turnover, reduce inventories of raw materials and goods in process — all vital under limited production and highly competitive conditions.

• And time-saving is but *one* of the economies LAMSON CONVEYORS can effect!

• Perhaps a slight change in your present production system will turn the trick. Now is the time to find out — while your "conveyor dollar" buys more and money for plant improvement is available. Let us give you the facts about conveyors — without obligation.

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Yes, I'm interested in finding out if you can cut our production costs. Send your Book, without obligation.

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UNIT HEATERS—Bulletin U-3, on utility unit heaters for general purpose heating.—L. J. Wing Mfg. Co., 14th St. and 7th Ave., New York.

UNIT HEATERS—Data Book No. 537, covering line of unit heaters.—Fedders Mfg. Co., Inc., Buffalo, N. Y.

VACUUM PUMPS—Bulletin No. 166, describing air-cushion-valve vacuum pumps.—Pennsylvania Pump & Compressor Co., Easton, Pa.

WATER METER—Bulletin M-975-B31, on Model R disk water meter.—Worthington-Gamon Meter Co., Harrison, N. J.

WELDING—Booklet, describing arc welding electrodes and accessories.—The Lincoln Electric Co., Cleveland.

Welding—Booklet, title "Automatic Arc Welding by the Electronic Tornado."—The Lincoln Electric Co., Cleveland.

WELDING—Booklet, title "The Repair of Damaged Cast Iron Machinery."—The Linde Air Products Co., 30 East 42d St., New York.

WELDING—Bulletin No. HW-4, on complete line of arc welders.—Harnischfeger Corp., Milwaukee.

WELDING TIMERS—Folder, describing electro-mechanical welding timers.—Welding Timer Corp., Chrysler Bldg., New York.

WIRE ROPE SLINGS—Folder, describing Drew wire rope slings.—Macwhyte Co., Kenosha, Wis.

WIRING ACCESSORIES—Bulletin No. 15, listing line of sockets, switches, plugs, fuses, etc.—The Bryant Electric Co., Bridgeport, Conn.

Books

•

BUSINESS OFFICES

G. L. Harris, vice-president, American Management Association. Harper & Brothers, 49 East 33rd St., New York. 238 pages, index. $2.50.

Describes operations of typical departments of a business organization. Office and clerical responsibilities are defined, records needed are described, procedure and personnel considered.

•

1935-36 MECHANICAL CATALOG

The American Society of Mechanical Engineers, 29 West 39th St., New York. 338 pages.

Contains catalogs of industrial equipment materials and supplies, describing more than 1,500 products; alphabetical list of manufacturers with notes on products they make; and a classified index listing products and telling what concerns make them.

•

On the Calendar

JANUARY

9-11, American Engineering Council, annual meeting, Washington, D. C. Frederick M. Feiker, executive secretary, 744 Jackson Place, Washington, D. C.

28-31, American Institute of Electrical Engineers, winter convention, New York. H. H. Henline, national secretary, 33 West 39th St., New York.

MARCH

3-6, Sixth Packaging Exposition, Hotel Pennsylvania, New York.

ONE UNIT HEATS BOTH FACTORY AND OFFICE

Simplified Installation Saves Considerable in First Cost

PLENTY OF WARM AIR IN PLANT WORKING ZONE NO NOISE IN OFFICE

By a little ingenuity Clarage Engineers have saved this company an interesting amount in the cost of heating equipment. As the illustration shows, warm air is piped from one of the unit heater outlets to the office—both factory and office effectively heated with a single unit.

And there is an additional economy due to a much more simplified steam and return piping layout. Also one decided advantage—no unit heater operating noise to distract office employees from their work.

This type of installation is possible only because Clarage Unitherm Unit Heaters are equipped with positive centrifugal fans which deliver warm air equally well with or without piping, and because these fans are designed with a self-limiting horsepower characteristic which protects against motor overload under any operating condition.

Syncrotherm Control Reduces Operating Cost

Another important and exclusive feature is Clarage Syncrotherm Control. Briefly, Syncrotherm Control regulates temperatures entirely by controlling the amounts of return air passing through and around the heating coil. Heating is thus accomplished with relatively low temperature air—and money is saved every heating season.

Clarage Unit Heaters have Syncrotherm Control as standard equipment, and are built in sizes to meet any industrial need. It will pay you to investigate this superior product. Mail coupon for full details.

CLARAGE FAN COMPANY, Kalamazoo, Michigan.

Gentlemen: Please send me your FREE Bulletin 103 on Clarage Unit Heaters and Syncrotherm Control.

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your service proven bearings

exchange them for Ahlberg Ground Bearings at a saving of

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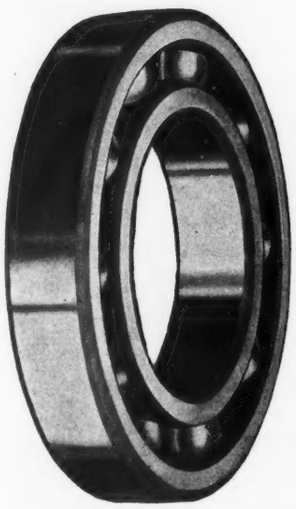

Don't junk worn ball bearings! They still possess their original worth in material. Exchange them for Ahlberg Ground Bearings and save on an average of 40% on every ball bearing replacement. Write for free booklet "The Story of Ahlberg Ground Bearings" and address of nearest Ahlberg Branch.

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321 East 29th Street, Chicago, Ill.

Ahlberg *Ground Bearings*
SERVICE PROVEN

RYERSON STEEL

[Also Copper & Brass]

—In Stock—
Immediate Shipment

- Hot rolled bars.
- Cold rolled bars incl. high speed screw and accuracy stock.
- Alloy steel bars, nickel, chrome, etc.
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- Babbitt.
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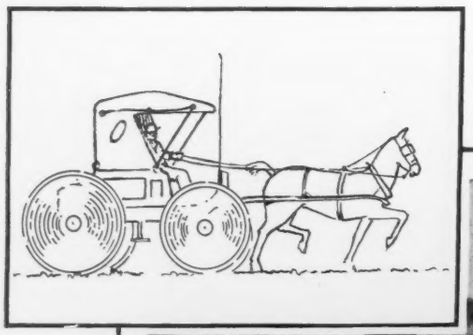

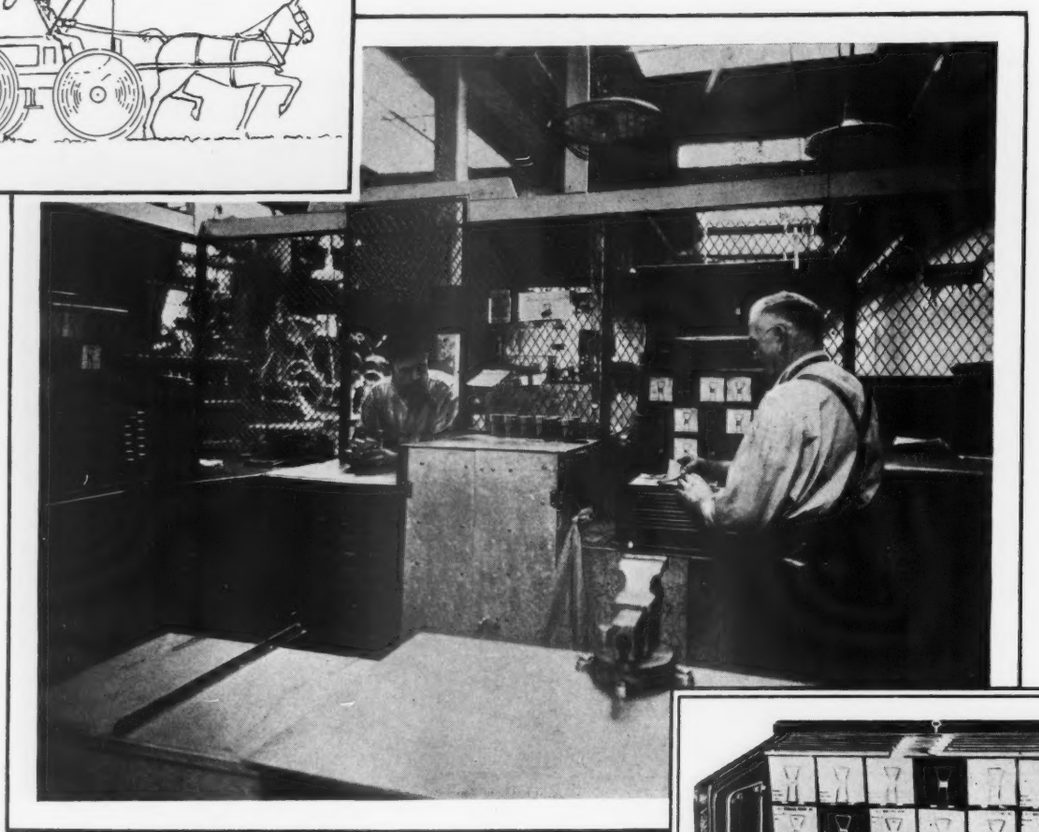

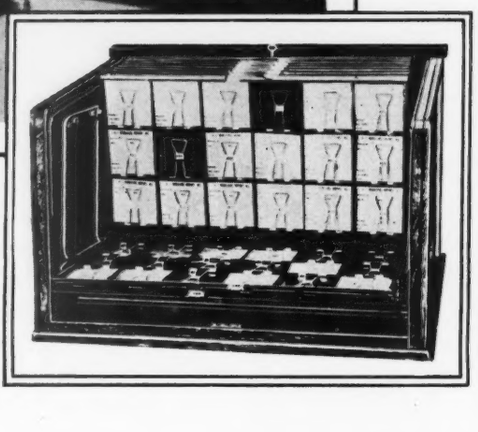

"As Obsolete as a Horse and Buggy"

That is the opinion of Axel F. Erickson, Secretary and Treasurer, and Works Manager, All-Steel Equip Company, Aurora, Ill., in his letter of June 18, 1935, when he refers to the brass tool check system which they discarded in 1919. Of the McCaskey System which they installed at that time, he says:

"—the McCaskey Cabinet gives us a perpetual inventory of tools.

In our tool room, every tool, die, or other piece of equipment has its standard place—even to brooms, hose, crowbars, etc. Twice a year all tools are called in for a check-up; and as every workman knows that any tool charged against him and not turned in will be taken out of his next pay check, we have a remarkably low tool loss.

The McCaskey System soon pays its way in reduced tool loss, while having the workman's signature absolutely eliminates arguments, evasions, or any unpleasantness."

The McCaskey System is a most efficient Industrial Control System for:

Steel Plants
Metal Products Plants
Wood Products Plants
Automotive Products Plants
Paper Products Plants
Clothing Products Plants
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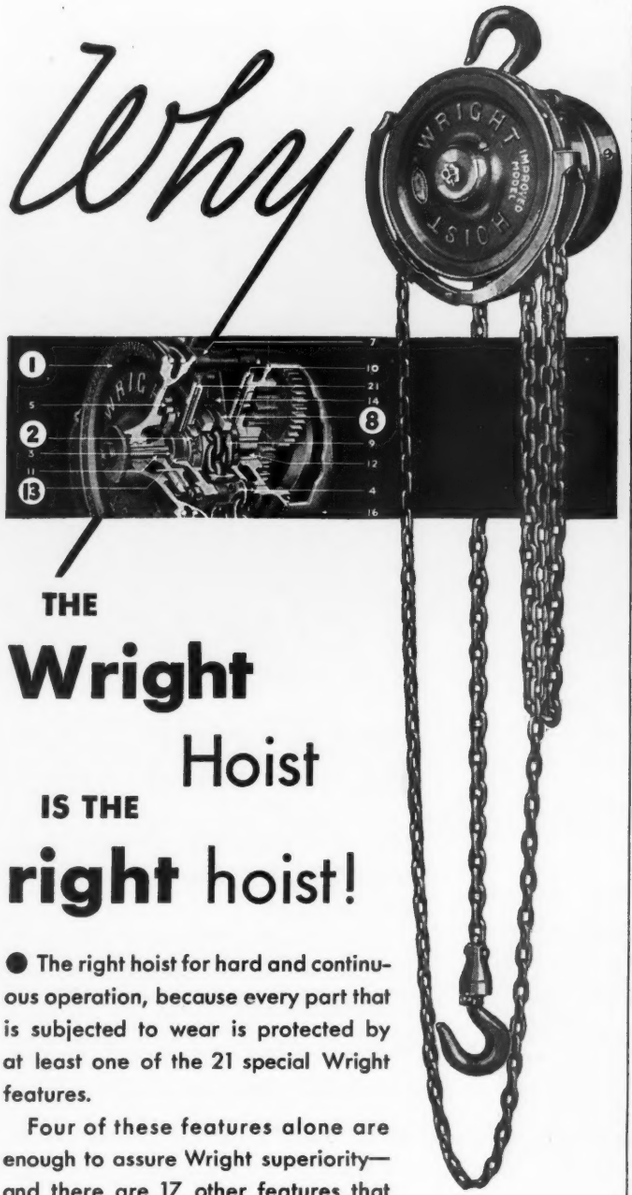
Shoe Manufacturers

The McCASKEY REGISTER Co.

McCASKEY ONE WRITING SYSTEMS

Industrial Division 1125 *ALLIANCE, OHIO*

Why



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Wright Hoist

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right hoist!

● The right hoist for hard and continuous operation, because every part that is subjected to wear is protected by at least one of the 21 special Wright features.

Four of these features alone are enough to assure Wright superiority—and there are 17 other features that add to the convenience and economy of Wright Hoists in service.

A zinc-coated finish is found only on Wright Hoists. Precision ball-bearings are positively grease-sealed with ground inner and outer races. A load chain safety guard prevents the load-chain from riding out of the pocket. A ball-bearing spindle increases efficiency, reduces wear and assures alignment at point of greatest speed.

Write for FULL information on the Wright Improved High Speed Hoist

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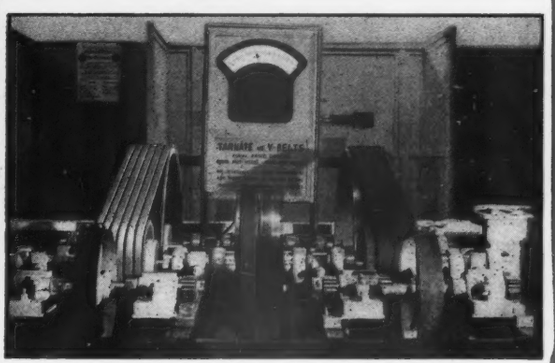
WRIGHT MANUFACTURING DIVISION OF THE AMERICAN CHAIN COMPANY, *Incorporated*
YORK, PENNSYLVANIA

In Business for Your Safety ACCO

WRIGHT *Improved* High Speed Hoists

RHOADS TANNATE LEATHER BELTING



IMPORTANT DEMONSTRATION

In several Industrial Shows, we have exhibited the machine pictured in the above cut. The difference which it showed in favor of a Rhoads Tannate Flat Belt Drive as compared with a V-Belt Drive was clearly evident to the layman and could be checked by an engineer.

These results were a revelation to Industry. They showed that the Flat Leather Belt Drive consumed about 2% less power based on the rated capacities of the drives than did the V-Belt Drive.

You with many others probably have places where a Rhoads Tannate-Rockwood Short-center Pivoted Base Drive would save you money (as compared with the V-Belt Drive) in installation and upkeep, and give you longer life and less interruption to production.

Ask our salesmen and engineers, or write for further details.

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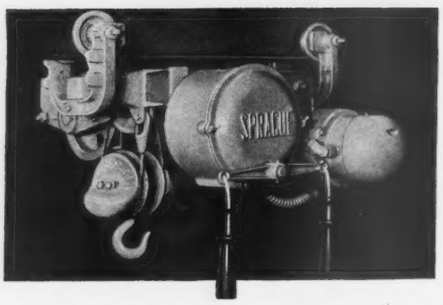
PHILADELPHIA, 35 N. SIXTH ST.
NEW YORK, CHICAGO, ATLANTA
CLEVELAND, WILMINGTON, DEL.

SPRAGUE

Close Headroom

ELECTRIC HOISTS



● **Features: 1. Absolute minimum of headroom consistent with safe, durable construction. 2. Direct worm drive. 3. Few moving parts. 4. Totally enclosed. 5. Automatic lubrication. 6. Noiseless operation. 7. Rope or push button control. 8. Anti-friction bearings. 9. Ball bearing trolleys with swivel yokes permit hoist to negotiate curves of small radius. 10. Hoist frame supported by trolley yokes and not suspended from king pin.**

SPRAGUE HOIST DIVISION

SHEPARD NILES CRANE & HOIST CORPORATION

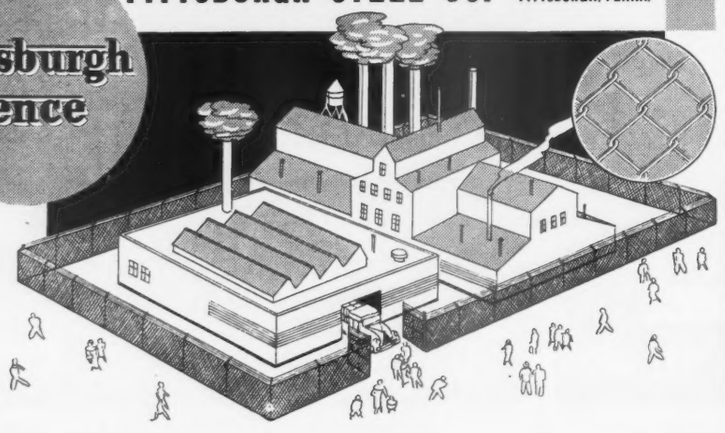
364 South Schuyler Avenue, Montour Falls, N. Y.

SOONER OR LATER EVERY PLANT NEEDS THIS PROTECTION

A property protected by Pittsburgh Chain-Link Fence is always prepared for the emergency when it comes. Besides, it pays for itself by its daily service in preventing petty thievery, and in the orderly control of ingress and egress from the plant. Pittsburgh Fence is sturdily constructed for long life with hard usage. We will be glad to estimate the cost of fencing your plant.

PITTSBURGH STEEL CO. 760 UNION TRUST BLDG. PITTSBURGH, PENNA.

Pittsburgh Fence



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READ THIS ONE

Our tale concerns the brushes required by much electrical equipment.

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From a technical standpoint, we calculate such things as current drain, peripheral speed of the commutator or rings, contact resistance, etc., but only... this is important... as a base on which to apply our *experience*.

You and every other manufacturer, owner or operator of motors and generators must depend in a large measure on the composite experience gained by your brush supplier from scores of applications similar to yours.

The Ohio Carbon Company stands ready to act as your "clearing house" of brush experience.

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For the Rest of the Story...Write

THE OHIO CARBON CO.

12508 BEREA ROAD CLEVELAND, OHIO

HAVE the Stamina Required for Hard Continuous Service » » »

Dodge-Timken Bearings are known to industry everywhere as rugged aids to low cost power transmission . . . There is a type of Hanger Bearing, Pillow Block or Unit Mount for every service—they are used for power transmission and are built into many production machines. For normal or heavy service—for excessive dust or water conditions there is a Dodge-Timken designed and built for the job . . . Dodge-Timken Bearings are completely assembled, factory adjusted, pre-lubricated units ready to install on a shaft . . . Stocks are available in all principal cities and large reserve stocks are carried at the factory. » » »

DODGE MANUFACTURING CORPORATION
MISHAWAKA, INDIANA, U. S. A.

New!

The third edition of Catalog D-30-Jr. describing Dodge Power Transmitting Equipment is just off the press. A copy will be sent to you on request.

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WORTHINGTON MULTI-V-DRIVE

- CORRECTLY RATED
- EXPERTLY DESIGNED
- ACCURATELY MADE

...Assuring uniformly excellent performance and enduring service

FOR any type of equipment ... Worthington Multi-V-Drive provides an effective solution for many drive problems.

- *Positive grip*
- *Permanently quiet*
- *Ideal for close centers*
- *Full efficiency maintained*
- *Negligible maintenance costs*
- *Full performance in any position*

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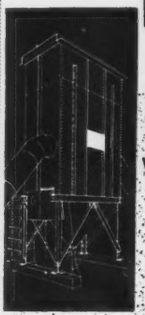

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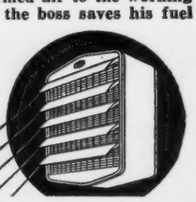
HERMAN NELSON hiJet HEATERS



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A NEW CONCEPTION OF FLEXIBILITY IN MACHINE DRIVES

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This machine has seen continuous 24 hour service frequently for seven years without a cent for repairs.

Hele-Shaw Fluid Power eliminates accumulators, intensifiers and complicated and expensive piping or packing, supplies high, non-fluctuating pressures, allows quick, infinite adjustment of pressures over the whole test range by remote control, applies and sustains pressure automatically, consumes power only during the application of and in proportion to pressures and leakage, and idles at no load.

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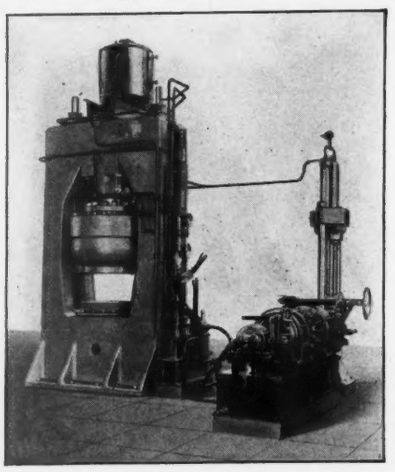
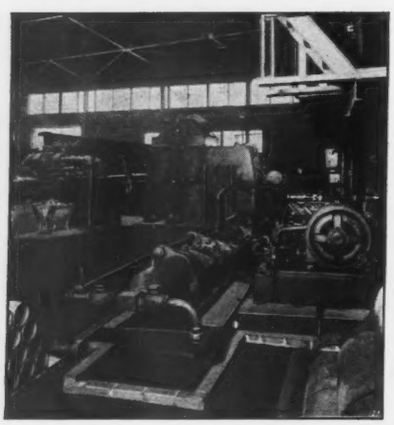
This R. D. Wood Special purpose press, capacity 2080 tons is powered by two Hele-Shaw pumps, one high pressure (2500 lbs. per sq. in.) for operating the intensifier and filling the check valve and one low pressure (1000 lbs. per sq. in.) for the pushdowns and pullbacks. Both pumps are driven by a single electric motor.

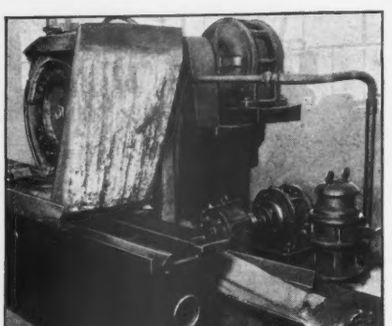
Fluid Power is used in presses of all types, straightening, molding, flanging, forcing, forming, flattening, swaging, shearing, assembling, etc. and in a countless number of ram-type machines.



VARIABLE GRINDER TABLE SPEED

A Hele-Shaw Type S Transmission has driven the table of this Diamond grinder for 7 years. The Type S transmission consists of a Hele-Shaw hydraulic pump direct-connected to an electric motor (just below the center, right, of the illustration). The hydraulic motor end is conveniently geared to the table drive. The table feeds smoothly and reverses automatically—slowly or as fast as you can snap your finger.





ON LARGEST U. S. LINERS

Hele-Shaw pumps drive the A-E-CO electro-hydraulic steering gears aboard the S. S. Manhattan and the S. S. Washington of the United States Lines. These two boats are the largest commercial vessels ever built in this country. The dual Hele-Shaw units develop a pressure of 1500 lbs. per sq. in. to operate a steerer designed for a torque of 33,000,000 inch lbs.

Fluid Power makes for simplicity in construction and arrangement of the steerer, ease of applying follow-up, responsiveness; protects the rudder from wave shock and requ res less power. The steerers of hundreds of commercial, naval and pleasure craft are Hele-Shaw driven.

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FLUID POWER, applied through Hele-Shaw pumps or transmissions, for producing variable, reversible linear or rotary motion is seldom an "over-the-counter" proposition. Our Engineering Department, skilled in the application of Fluid Power to the diverse problems of industry, will gladly determine its possibilities for you.

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2426 Aramingo Avenue, Philadelphia, Penna: Please send me, without obligation, your new catalog of Hele-Shaw Pumps, Motors and Transmissions.

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–Except for Control

The lighting job in this plant was skillfully engineered. Every working surface has 15 foot-candles of illumination . . . when lights are on. This level assures eye comfort for every worker, and efficient output from every production tool. Below this level . . . eyes tire, production lags, rejects increase.

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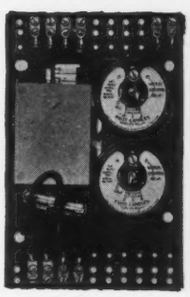
Weston Illumination Control Relays add but a small amount to the total cost of the lighting job . . . an amount so small that their use is most economical and desirable.

OUTSTANDING ADVANTAGES OF *PHOTRONIC CONTROL



1. Light intensity "on" ½ foot-candle up.
2. Light intensity "off" ½ foot-candle up.
3. Energy consumed operating — 2 watts for 1 minute.
4. Energy consumed not operating—0.
5. Employs life-time, self-generating PHOTRONIC Cell.
6. Cell operates sensitive relays direct, no outside voltage, no amplification.
7. Sensitive Relays operate main circuit direct by small clock motor—no auxiliary relays.
8. Outdoor Model in water-tight box—for pole mounting.
9. Indoor Model in attractive case for wall mounting.
10. Installation simple—maintenance low.

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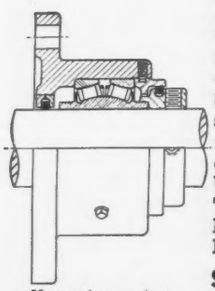

Note piston ring seals and square □ drive collar.

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Commercial Trust Building
Philadelphia, Pa.

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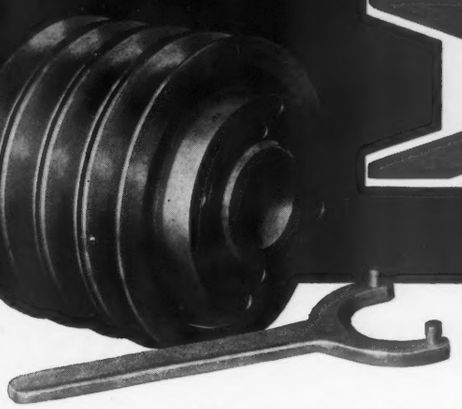
Cross-section of Vari-Pitch Sheave and Texrope Belt adjusted for minimum diameter — low speed.

THE NEW Vari-Pitch TEXROPE SHEAVE



● The new Vari-Pitch Texrope Sheave, now offered by the Allis-Chalmers Mfg. Co., represents a vitally important development in power transmission. ● By a simple adjustment, which takes but a few moments, the diameter of this new sheave can be altered so as to give a variation in speed of from 15 to 25 per cent per sheave; if both sheaves are of this type a 30 to 50 per cent variation in speed is possible. This permits you to take advantage of higher speed cutting tools; it permits you to experiment with different speeds to ascertain at just what speed your machines show the greatest efficiency; it permits you to make different products, some of which require higher speeds and some lower — and do all this without dismantling and buying new drives, but simply by taking a few moments to make the desired adjustment. ● Vari-Pitch Texrope Sheaves are for manual and automatic adjustment. The manual type is recommended for applications that require occasional changes of speed. For applications that require frequent changes the entirely automatic type is recommended in which speed can be instantly varied to full range while the drive is in operation.

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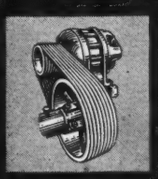
ORIGINATED BY ALLIS-CHALMERS



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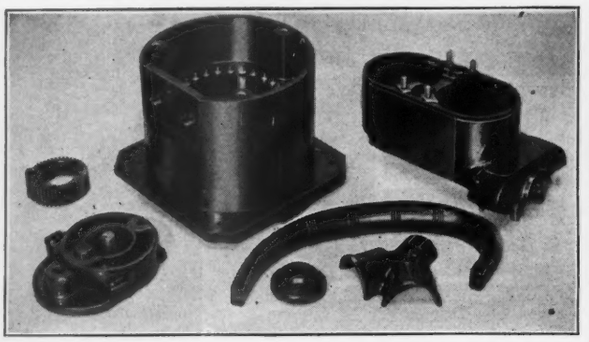

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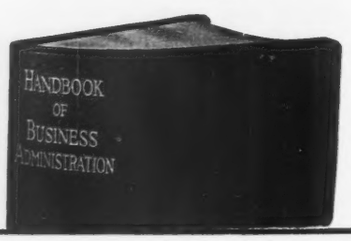

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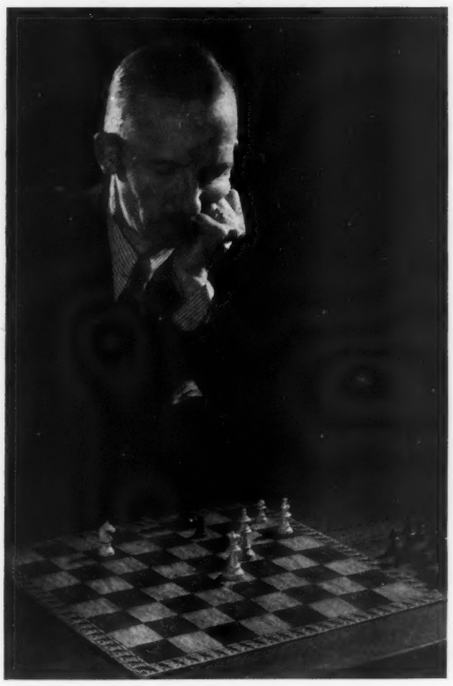

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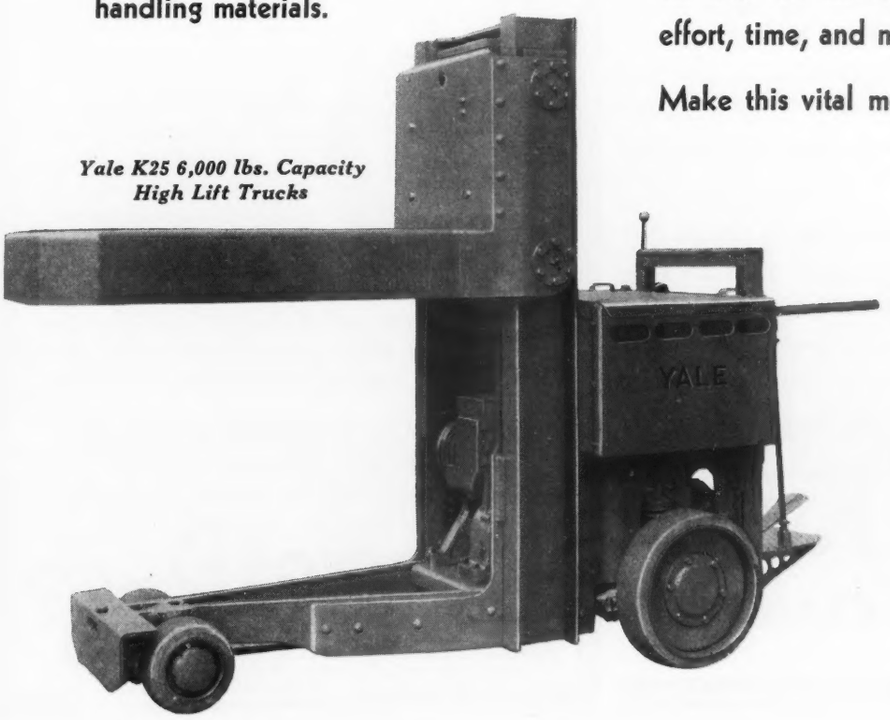

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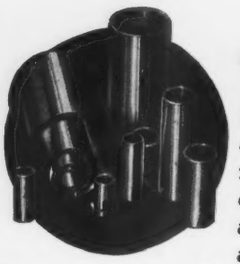

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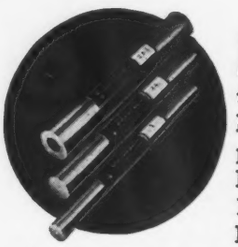

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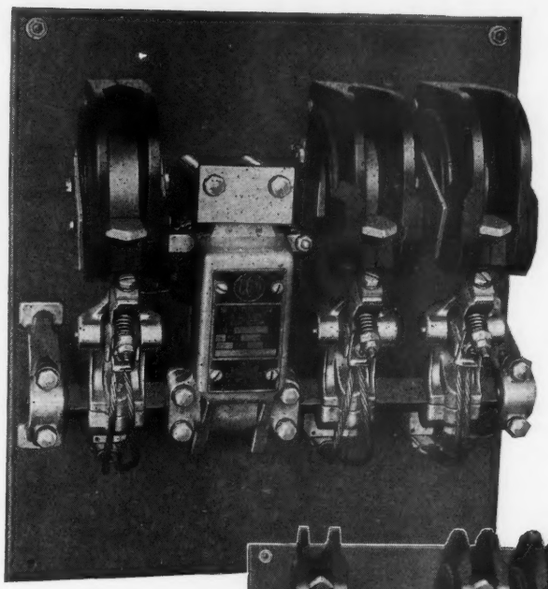

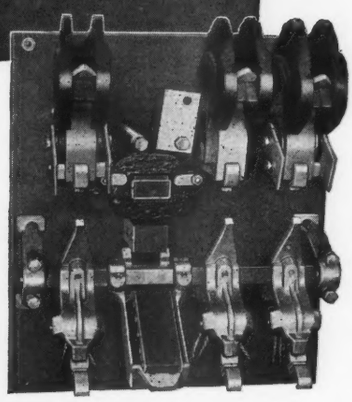

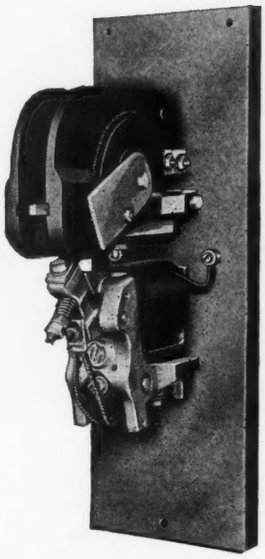

These views show the 100 ampere sizes of the Type LTZ 3-pole a-c and Type LT single pole d-c contactors mounted on bases of standard size. Where required, smaller bases just large enough to accommodate the overall dimensions of the contactor are available. Contactors can be supplied in back-connected, unit style as illustated; also front connected and when desired, either style can be enclosed in a cabinet suitable for the conditions encountered. Unassembled contactors are available for remounting on switchboards and similar panels.

The NEW EC&M LINE-ARC CONTACTORS

With moving parts light in weight, capable of high speed operation, and with the construction of strong, fine-appearing aluminum alloy, these new EC&M Contactors mark a revolutionary change in magnetic contactor design . . . . a development of outstanding importance to industry.

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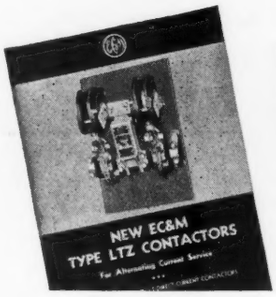

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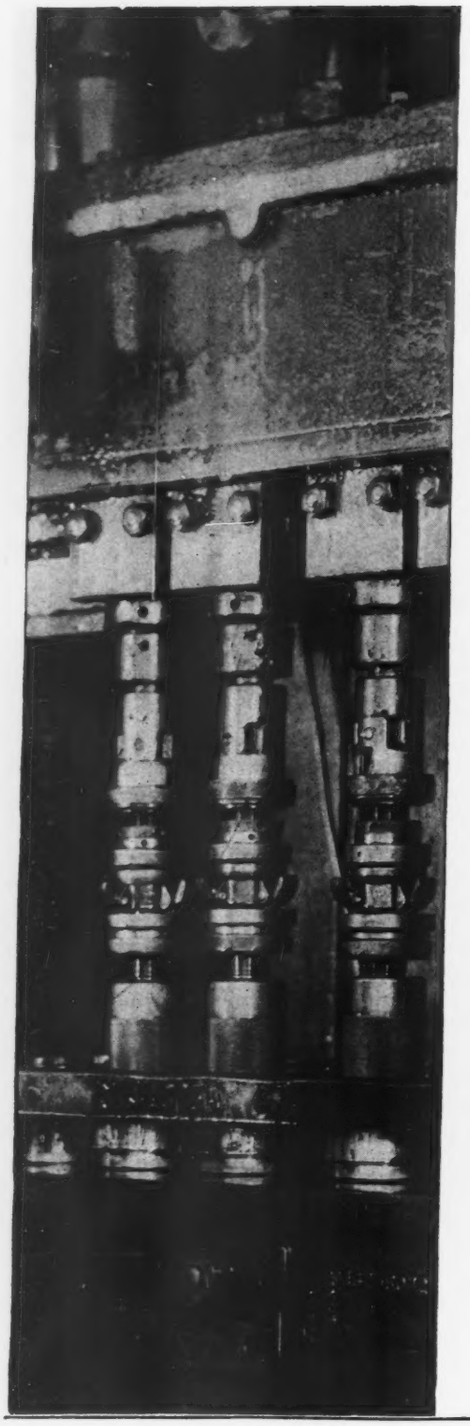
Address .....

FM&M-12-35



It's time to *tool-up* to produce orders

HAVE you ever realized that sales production is a manufacturing job? Just like building automobiles?

Sales can be built up slowly and laboriously "by hand" at tremendous cost. Or they can be processed, assembled and turned out on a production basis, at extremely low unit cost . . . if you tool-up properly to do it! Selling to business and industry calls for the proper combination and *intensive* use of several selling tools.

Industrial Advertising is one of those sales tools. It can and will do a part . . . a big part . . . of the sales job. Properly used in combination with direct selling, and other sales tools, it helps to manufacture orders on a production basis.

Industrial Advertising in McGraw-Hill Publications calls regularly on the same men your salesmen see. It *also* calls on the men whom they *cannot* see. Executives! Holding company officials! Up-the-line management and down-the-line workers! All the men in every plant, who have anything to say about the buying of industrial goods and equipment!

Industrial Advertising of this kind, at a cost averaging only a little more than one cent per call,—is a powerful sales tool, and an economical one. Put it to work to help produce more orders for your business.

McGRAW-HILL PUBLICATIONS

McGraw-Hill Publishing Company, Inc., 330 West 42nd Street, New York, N. Y.

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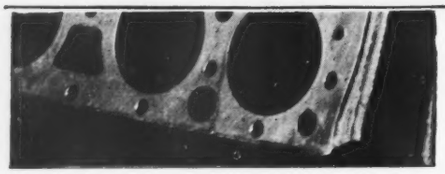
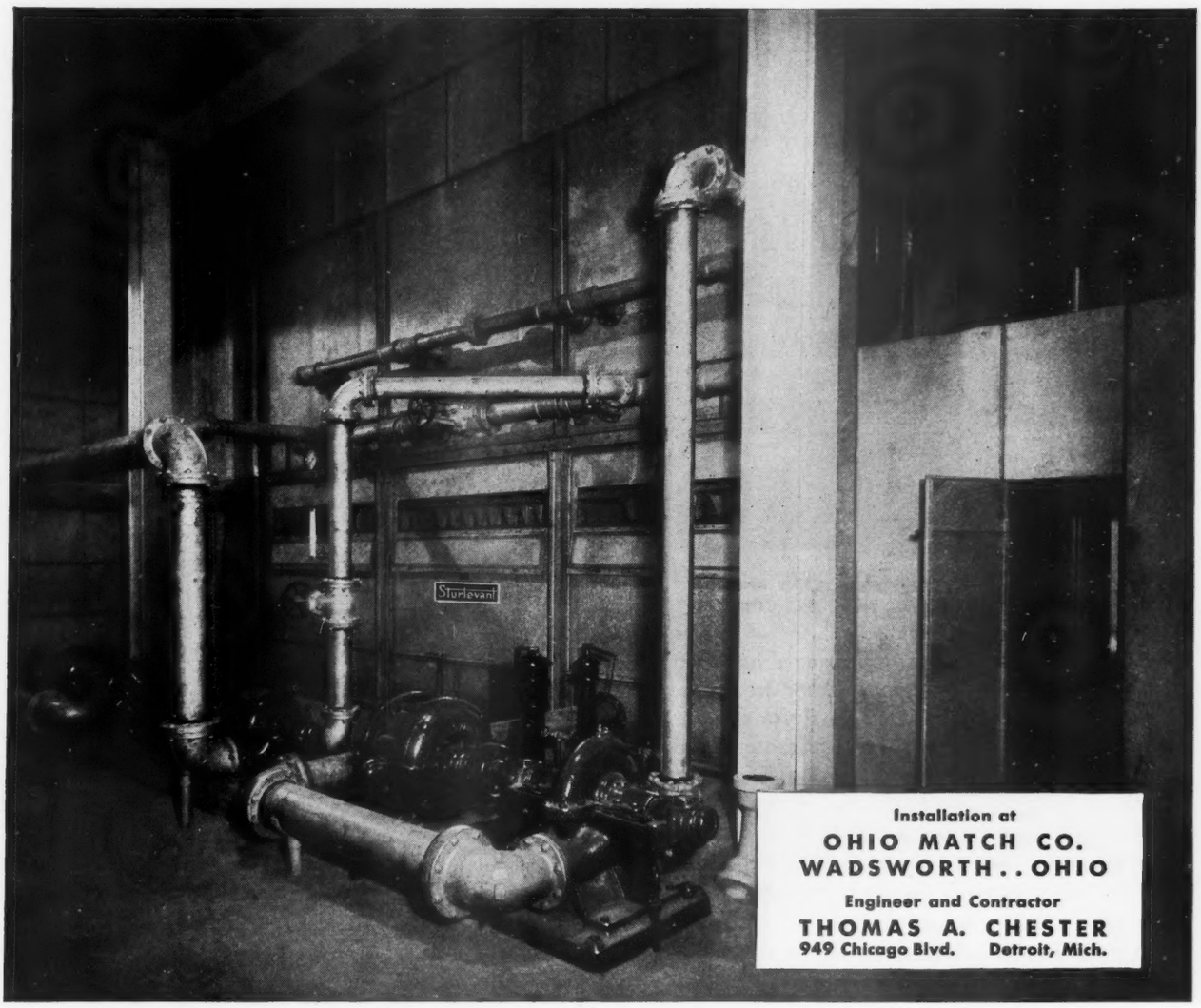


STURTEVANT AIR WASHERS FOR INDUSTRIAL AIR CONDITIONING

(One of the Largest Dehumidifiers Ever Installed Shown Here)



32 feet wide...16 feet high...21 feet, 9 inches long! These are the dimensions of this Sturtevant Three-Stage, Double Deck Dehumidifying Air Washer installed at the Ohio Match Company, Wadsworth, Ohio.

Big job or small...you can get Sturtevant Air Conditioning or Ventilating Equipment to exactly meet any need...Fans, Air Washers, Heating Surface, Cooling Surface and Dehumidifiers ...individual units of equipment or complete systems. The most comprehensive variety of types and sizes available...the result of Sturtevant's 70 years of air engineering experience and constant product development.

We would welcome your inquiry for further information about any of this Sturtevant equipment in which you are interested.

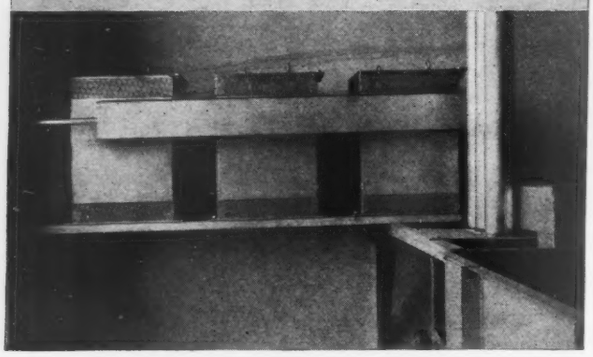
B. F. STURTEVANT CO., Hyde Park, Boston, Mass.
New York, N.Y., 420 Lexington Ave. Chicago, Ill., 400 N. Michigan Ave.
San Francisco, Cal., 681 Market St. *Branch Offices in Other Cities*
B. F. STURTEVANT COMPANY of CANADA, Ltd., GALT.
Sales Offices in Toronto and Montreal *Repres. in Principal Canadian Cities*

Sturtevant
REG. U. S. PAT. OFF.

Fans, Blowers, Air Washers, Air Conditioning, Heating, Vacuum Cleaning, Drying, Mechanical Draft Equipment

How to Eliminate those long runs of 115-volt lines

Carry your modernization to completion by installing G-E air-cooled transformers



These three 20-kva transformers supply power at low voltage, where needed, from 460-volt circuits

YOU have replaced your long runs of line shafting, because individual or group motor drive has been found to be more efficient, less costly to operate and maintain, safer, and neater in appearance. Take the next step in progressive modernization. Eliminate the *electrical* "long-run line shaftings"—those inefficient long runs of 115-volt lines. Keep those runs at higher, more efficient voltage, and install small G-E air-cooled transformers to provide the lower voltage only where you need it.

Let us tell you how G-E transformers can help you to modernize profitably. Call the nearest G-E sales office, or address General Electric Company, Dept. 6D-201, Schenectady, New York.

GENERAL ELECTRIC COMPANY
Dept. 6D-201, Schenectady, N. Y.
Please send me a copy of your bulletin GEA-897E, on "Air-cooled Transformers for Lighting and Power Service."
NAME.....
COMPANY.....
ADDRESS.....
320-62

GENERAL ELECTRIC

"HALLOWELL" Shop Equipment of Steel Is what You Need

Pat'd and Pat's Pend'g

Fig. 732—"Hallowell" Steel Work-Bench shelf below for additional convenience. Strong, rigid, with one-piece, smooth steel top, easy to keep clean. Shipped from stock, knocked down. Drawer *not* included.

GET BULLETIN

Pat Appl'd For

"Hallowell" No. 200W. H-B— Steel Stool

Dished wooden Seat 14½" dia. Heights: 14" to 30" incl. stepped up by 2". Adjustable Spring Posture-Back. Hinged Back-Rest. Welded throughout. Finish: Rich Olive Green Enamel.

"Hallowell" No. 200W— Steel Stool

Dished wooden Seat 14½" dia. Heights: 14" to 36" incl. stepped up by 2". Welded throughout. Finish: Rich Olive Green Enamel.

GET BULLETIN

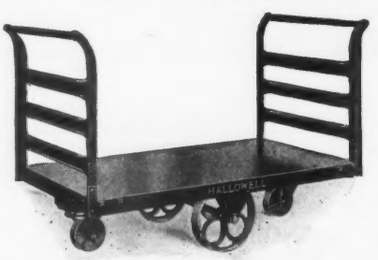


Fig. 769—"Hallowell" Steel Truck Wide range of standard sizes and types. Specials of any construction or dimensions also furnished.

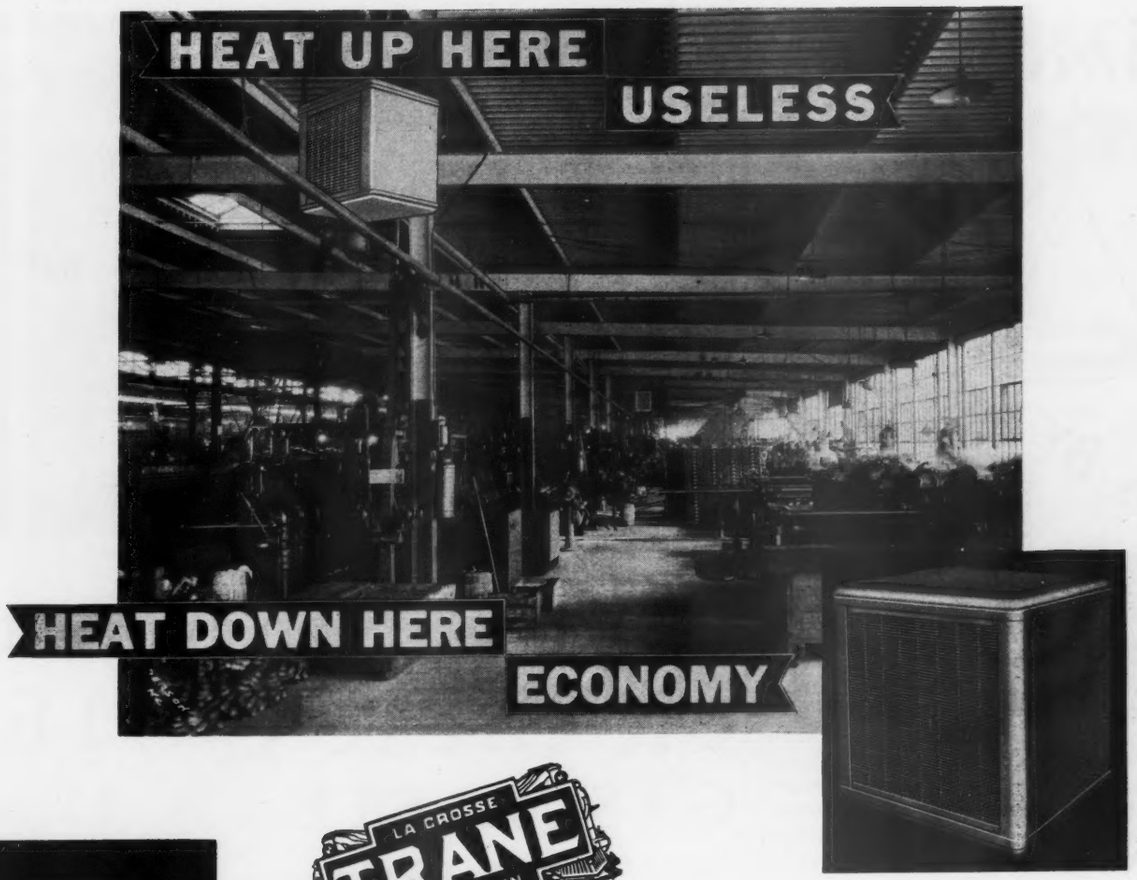
GET BULLETIN

STANDARD PRESSED STEEL CO.

BRANCHES BOSTON CHICAGO DETROIT

JENKINTOWN, PENNA. BOX 546

BRANCHES NEW YORK SAN FRANCISCO ST. LOUIS



LA CROSSE TRANE WISCONSIN

FLOOR LINE SPREAD UNIT HEATERS . . . *Provide Economical Heat*

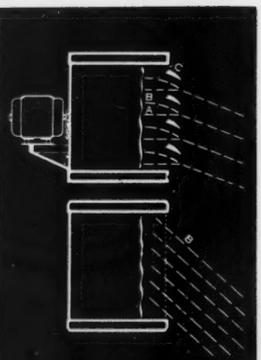
Your building needs a heating system that will spread heat down in the working zone. That is why TRANE "Floor Line Spread" Unit Heaters are so popular. They spread the heat in the working zone and spread it so effectively that fuel bills will be cut as much as 25% to 30% on many installations.

Along with the exclusive feature of "Floor Line Spread" is the famous TRANE Heat Transfer Coil so widely used in heating and air-conditioning equipment. The combination of these two outstanding features is your assurance that a TRANE Heating System is the economical method of heating your building.

Whether you install a complete TRANE UNIT Heating System or spot a few Units here and there to overcome cold spots and drafty conditions, there is a Unit of proper size and type to meet your requirements.

The coupon below will bring complete information on both the TRANE Propeller Fan Type Units and the TRANE Blower Fan Type Units, and there is a TRANE Branch Office near you to assist in making the proper selection.

THE TRANE COMPANY LA CROSSE, WISCONSIN



THE difference in heat distribution between a Trane "Floor Line Spread" Unit Heater and the ordinary Unit Heater lies in the elimination of one "force."

Above is the distribution from an ordinary unit heater. Line "A" represents that stream of air which is not affected by the louvre "C". Line "B" represents the stream air that is turned downward by the louvre.

In other words, the stream is controlled by two forces—one attempting to rise, the other being forced upward—A STREAM OF FIGHTING CURRENTS.

Below is a Trane "Floor Line Spread" Unit Heater. Note the absence of Line "A". All of the air is directed towards the floor. ONE FORCE AND THAT DIRECTING THE AIR TO THE FLOOR.

NO COMBAT—
NO FIGHTING CURRENTS.

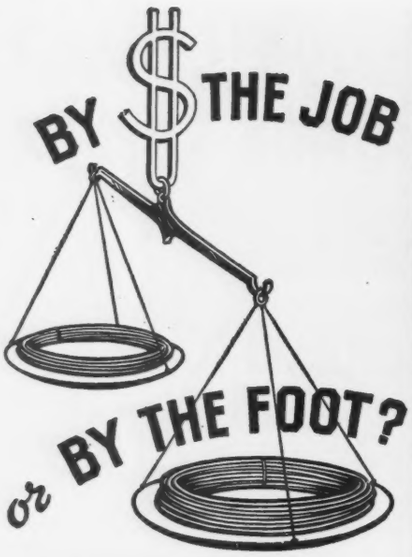
And note the neat, compact appearance that the Trane Freeflo grille brings to the unit—the smartest looking as well as the most efficient unit on the market.

The TRANE COMPANY, Dept. M-12, La Crosse, Wisconsin

Please send complete data on TRANE Unit Heating Systems.

Name .....

City ..... **State** .....



Here's a paradox. *By the foot* Rockbestos wire and cable may cost more than non-asbestos protected constructions — *by the job* it often costs *less!* The answer is that a Rockbestos wire circuit, either open or in conduit, can be the *shortest distance* between two points, regardless of boilers, kilns, steam pipes and other enemies of ordinary insulation. Thus, the heat resistance and long life characteristic of Rockbestos insulated wires and cables can often be yours without extra material cost, not to mention time saved in installation.

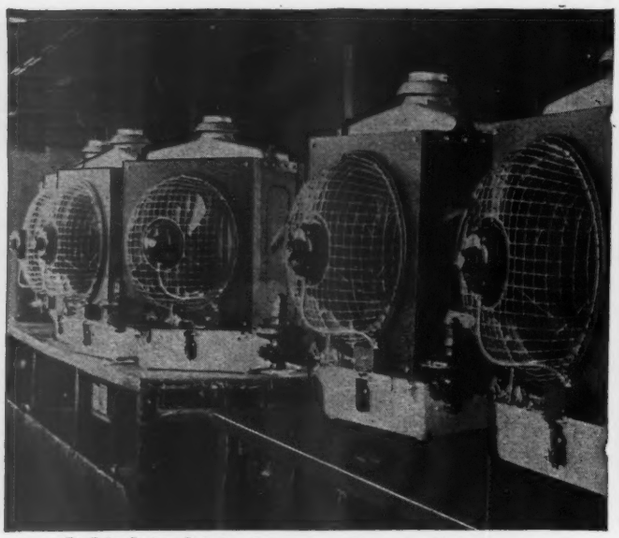
We will gladly explain the insulation construction of our wires, cables and cords, detailing the qualities that make Rockbestos the wire for severe service requirements — and, if possible, will recommend from our more than fifty standard types the one adapted to your particular need. Specifications and quotations also given on special constructions.

A.V.C. Boiler Room Wire

Rockbestos A.V.C. wire and cable is available in any required size up to 2,000,000 C.M. and for service voltages up to 7500. Our catalog shows many types and suggests applications. Send your request for one to Rockbestos Products Corporation, New Haven, Conn.

ROCKBESTOS

the wire with permanent insulation



Buffalo Suspended Gas Heaters provide warm air at low cost

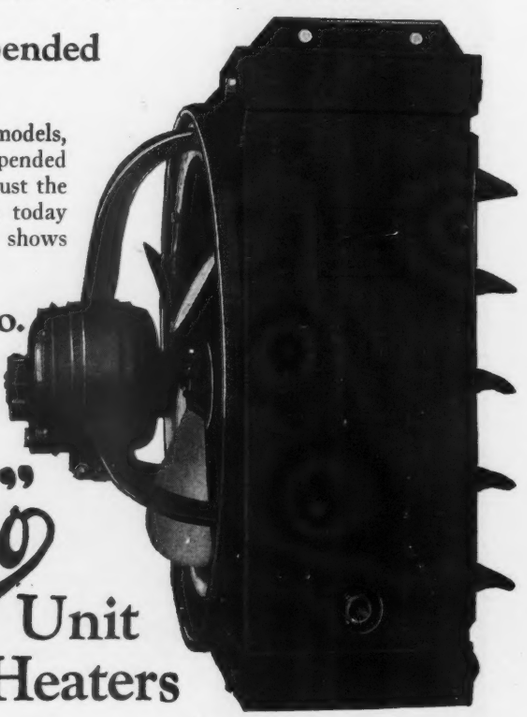
Stock Shipment on these QUIET GAS or STEAM Units

If you need prompt shipment on unit heaters, "Buffalo" can take care of you. Because these QUIET, tested units are so largely used thruout Industry, we have all popular sizes ready for immediate delivery.

Remember, when you select Unit Heaters, Buffalo engineers have been building efficient, sturdy units, quiet enough to pass the most rigid requirements for many years. They are not new or experimental.

Floor and Suspended Types

In both gas and steam models, full lines of floor and suspended types make selection of just the right type easy. Write today for Bulletin 469 which shows all models.



Buffalo Forge Co.
471 Broadway
Buffalo, N. Y.
In Canada: Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

"Buffalo" Unit Heaters

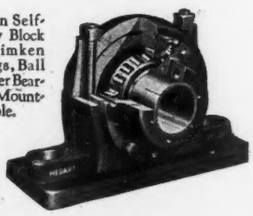
CUT TRANSMISSION LOSSES *by* CUTTING FRICTION LOSSES

●●●●●●●●●

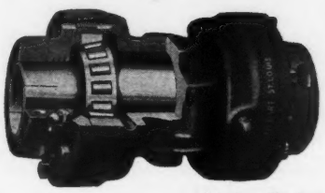
Install Medart-Timken Pillow Blocks, Hanger Bearings, Flange Units and Unit Mounts! Cut down Friction and consequent Power Losses . . . Insure Smoother Operation . . . Long Life . . . Trouble-free Service.

Medart-Timken Bearing Units are furnished in 4 types: *For general purpose applications*—"SS" Straight Sleeve Series Units . . . *For high speeds and shock loads*—"TS" Taper Sleeve Series Units . . . *For conveyor and machinery applications*—"DM" Direct Mounted Series Units . . . *For light duty general purpose applications*—"DC" Dog Collar Series Units.

CUT COSTS



Medart-Timken Self-Aligning Pillow Block . . . Medart-Timken Flange Bearings, Ball and Socket Hanger Bearings and Unit Mountings also available.



Medart-Timken Ball and Socket Hanger Bearing.

PEAK POWER TRANSMISSION ECONOMY

Cut transmission costs with Medart V-Belt Drives—Medart-Sheaves—Medart V-Belts.

More effective power transmission. Uniform drive and positive speeds result from uniform tension and extreme flexibility. No vibration—both driving and driven machines run more smoothly . . . operate on short centers.

Medart V-Belt Drive . . . Uniform tension, longer life, shorter belt centers, less space. Also V-Belt Sheaves.

Cast Iron, Pressed Steel and Light Duty Cast Iron Sheaves.

Medart Gears can be furnished in a complete range of sizes and types—cast iron, machine molded and cut—spur, miter and bevel.

For Every Power Transmission Need, specify Medart—"EVERYTHING IN POWER TRANSMISSION AND SPECIAL EQUIPMENT."

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Get Engineering Reference Catalogs 56G, "Gears"—56T, "General Power Transmission Equipment"—56V, "V-Belt Drives."

Medart Hangers—anti-friction or ring-oil bearings—all types—standard, universal, four and two-point adjustment.

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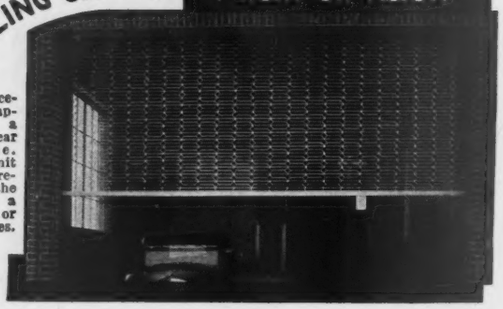
Engineering Sales Offices: Cincinnati, Cleveland, New York, Philadelphia, Buffalo, Chicago, Pittsburgh, New Orleans, San Francisco, Los Angeles, Dallas, Denver, Charlotte, Birmingham, Milwaukee

MEDART

KINNEAR ROLLING GRILLES

Protection— WITHOUT LOSS OF AIR, LIGHT OR VISION



Illustrates space-saving, neat appearance, of a large Kinnear Rolling Grille. The closely knit Grille-work prevents even the admittance of a man's hand or large projectiles.

JUST the thing for protection against rioting, trespassing, and burglary. An impassable barrier that can be permanently installed—raised and lowered quickly and easily, like a window blind. And when closed there's no sacrifice of air, light or vision. The Kinnear Rolling Grille is a product of proven merit, embodying the same construction principle as the famous *Kinnear* Steel Rolling Door. Built in any size or metal, the Rolling Grille can be installed in any old or new building. Let us tell you more about it.

Whenever you have any type of opening to close, first think of *Kinnear*—Manufacturers also of Kinnear Steel Rolling Service and Fire Doors, Wood and Steel Bifolding Doors, and Wood and Steel RoL-TOP (overhead type) Doors. No obligation for recommendations.

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FOR ANY INDUSTRIAL OPENING

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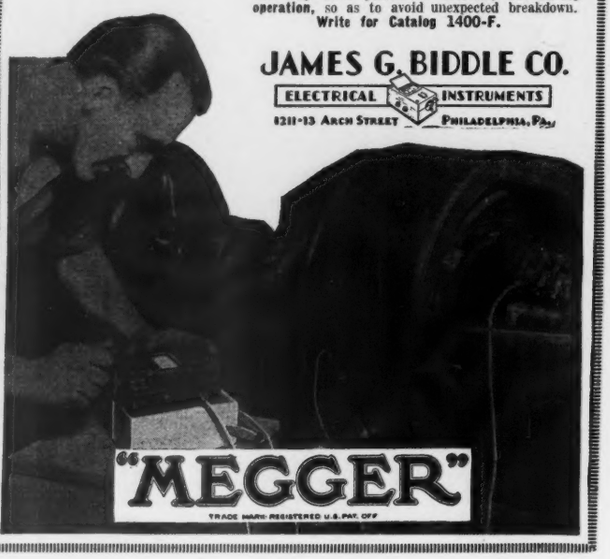
It is Good Insurance to make "MEGGER" tests of electrical insulation

"FROM 1927 to 1934 our plant was idle, and absolutely nothing was done toward electrical maintenance. . . . Upon being given the job of getting ready to operate the season of 1934 . . . we bought one of your 'Meggers' and I can truly say the cost has been saved many times over, especially during that period of renovation, when the wrong 'guess' concerning a certain piece of equipment, would have meant more than the cost of the 'Megger'."

From the Chief Electrician of a large western sugar company.

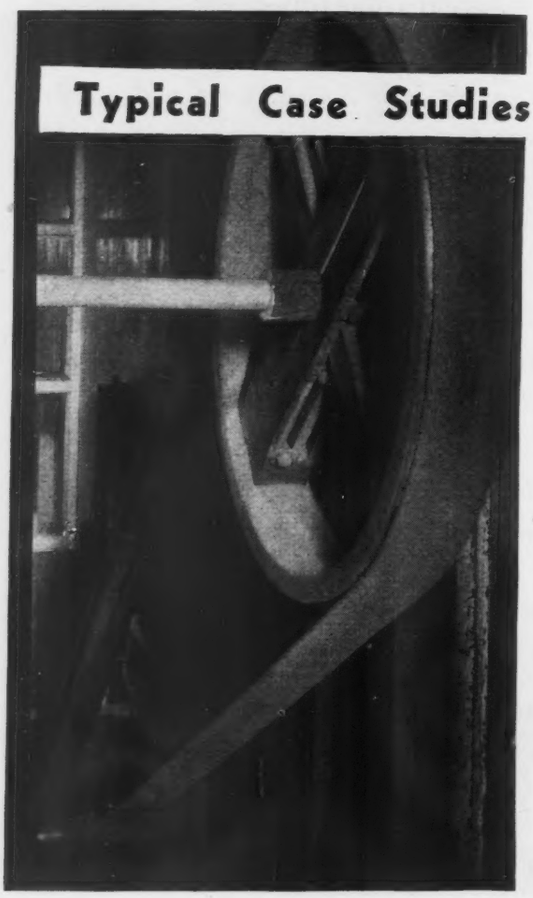
It is good **insurance** to make "Megger" tests, not only after periods of idleness, but **during operation**, so as to avoid unexpected breakdown.
Write for Catalog 1400-F.



JAMES G. BIDDLE CO.
ELECTRICAL INSTRUMENTS
1211-13 ARCH STREET — PHILADELPHIA, PA.

"MEGGER"
TRADE MARK REGISTERED U.S. PAT. OFF.

Typical Case Studies Prove the Performance Values of SCHIEREN BELTING



Industrial plants all over the world are the daily proving grounds for Schieren Leather Belting. You may believe that your transmission problems are different, but the case studies of hundreds of Schieren installations, operating under every conceivable condition, are proof that Schieren Leather Belts "can take it" and will deliver power unfailingly—at low maintenance cost.

You can learn why Schieren Belts are your best investment for power transmission if you will send for a copy of our recently published "Schieren-izing" booklet. We would be glad to send a copy to any Plant Operating Executive.

The installation, pictured herein, was made in 1912 and has given uninterrupted service, twenty-four hours a day, seven days a week. It is an installation in the Mutual Creamery Company at Salt Lake City, Utah.

X BAR BELTING
Chas. A. Schieren Company
ESTABLISHED 1848
Tanners and Manufacturers of
LEATHER BELTING, PACKINGS and SPECIALTIES
Main Office and Factory
33 FERRY STREET NEW YORK
Branches and Distributors in All Principal Cities

THE MOST ECONOMICAL BELT IS A SCHIEREN LEATHER BELT

Ask Your Production Committee to *try on* the New F-3100 FUL-VUE Goggle

Patented

They'll call the Ful-Vue the most comfortable goggle they've ever worn themselves—or asked their men to wear. They'll like the Ful-Vue's high-set end pieces that permit full vision . . . its handsome appearance . . . its full-rocking pearl nose-pads that eliminate nose irritation. They'll see first-hand why the Ful-Vue makes eye-safety programs easier to enforce . . . *why it saves more eyes and more dollars.* Another feature that will win their active approval is the Ful-Vue's new 6-Curve Super Armorplate Lens. Shaped to fit the eye area, it provides liberal clearance for eyebrows and lashes. *And it is twice as strong as any lens used before in standard safety goggles.* Send for the American Optical Company industrial representative stationed at the branch office near you. Try the Ful-Vue yourself. Get the men on your factory firing line to try it.

The Ful-Vue offers all-day-long comfort . . . unobstructed vision . . . the protection of the 6-Curve Super Armorplate Lens—twice as strong as lenses regularly used in standard safety goggles. Patented.

American Optical Company

Manufacturers, for more than 100 years, of products to aid and preserve vision. Factories at Southbridge, Mass. In Canada, Consolidated Optical Co., Ltd. Branch offices in all principal industrial centers

1895

McCORD

BETTER BUILT UNIT HEATERS

McCord Features

McCord engineered and built high efficiency all copper and bronze heating element, more heat—quiet high velocity fan—inlet and outlet pipes at rear, requiring less headroom, better appearance—new modern design shell—black crystal enamel finish—stainless steel trim—37 standard sizes—a size to meet every requirement—backed by McCord's 31 years heat transfer experience. Because of their modern attractive appearance and quiet operation they are adapted to office and store use as well as factory.

QUIET CLEAN-UNIFORM HEAT

WRITE FOR NEW CATALOG AND PRICE SHEET

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DETROIT, MICH.

The NEW

Paasche

HIGH PRODUCTION

Airbrush

HERE'S the latest development in an airbrush! The new Paasche UBCH. Possesses every feature that nationwide survey showed airbrush users most desired. This great airbrush advance will give you more uninterrupted hours of faster production and finer results than any other.

This new Paasche UBCH is but one of the units in the Paasche family of airequipment, the result of over 25 years' experience. No matter how satisfied you now are with your present finishing costs, the chances are that you can cut them 22% to 75%—thru the right combination of Paasche units.

Our confidence in saving you 22% to 70% is based on what we have done for scores of users of airequipment who were formerly completely and complacently satisfied with results.

Let one of our Paasche engineers study your needs and make suggestions. No cost. No obligation.

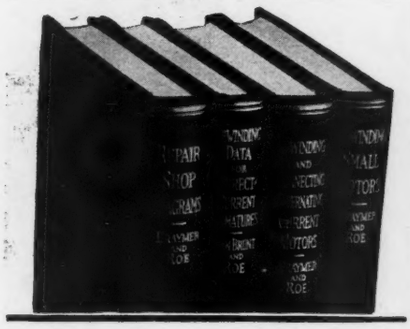
- Increased Production
- Smoother Coverage
- Complete Convertibility
- Greater Ease of Handling
- Lower Maintenance Costs

Write today for literature describing Paasche Air-Finishing Equipment

Paasche Airbrush Co.

1901 DIVERSEY PARKWAY CHICAGO

THE WORLD'S HEADQUARTERS FOR Industrial Aircoating, Airrubbing, Airfinishing Equipment, Manual and Automatic—Airbrushes for Artists—Paasche "No Offset" Process for Printers that Prevents Ink Offset and Smudging Without Slipsheeting.



NOW- how to repair and rewind all types of motors . . .

ELECTRIC MOTOR REPAIR LIBRARY

4 volumes, $10.00, payable in easy monthly installments

THIS set of books should be on the shelf of every man who ever has to touch a motor for purposes of repairing it or changing it to meet different operating conditions. In shop language and with practical shop methods it covers every step in stripping, rewinding and connecting a.c. and d.c. motors of all kinds.

Do you know how to:

—lay out a wave winding
—test a.c. and d.c. motors to locate grounds, shorts, opens, quickly and positively
—properly record data when stripping armatures so that it will be instantly usable for correct rewinding by yourself or any experienced winder at any time afterward
—determine how many coils can safely be cut out
—lay out single-phase fan motor windings
—change single-phase windings for two- or three-phase operation
—make cross or equalizer connections on lap windings
—lay out frog-leg windings
—handle every step in a rewinding job from the time it comes into the shop until it leaves
—wind stators for tubogenerators
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—rewind motors for voltage, speed, frequency, or cycle changes
—etc., etc., etc.

1,079 pages of practical shop methods and data on jobs like these in this library. A complete, modern key to repair of all motors. Nothing else in it; every page filled with definite, practical facts for the industrial maintenance man and the electric shop worker.

How to change motors for different operating conditions

Here is all the information you need in order to determine what changes various types of motors permit; to lay out new windings for specified service conditions; and to handle every step in the work with satisfactory results.

Covers all types of motors, from those used in small household and commercial appliances of all kinds, to mining and railway motors. Explains principles underlying the different types of winding; gives definite instructions for doing the various rewinding jobs. Also gives many data, tables and diagrams constantly needed by the repair man, including data difficult to get from any other sources.

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Incidentally, our Stock Assortment consists of nearly 2800 V-Belt Drives from 1/4 h.p. to 100 h.p. with at least a dozen selections of center distances for each. This allows us to furnish very promptly any Drive, V-Belt or Sheave requirement. However . . .

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Shafting, Hangers, Collars, Pulleys, Friction Clutches, Ball Bearings, Flexible Couplings, Rope Sheaves, Pillow Blocks, Belt Contactors, "V" Belts, "V" Belt Sheaves and complete "V" Belt Drives.

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CHROMALOX ELECTRIC HEATING UNITS solved it!

"Can we make steam electrically to heat platens?"

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"Yes. A small electrically heated boiler will give you a head of steam in 30 minutes. An automatic pressure switch to turn the generator on and off will maintain the desired steam pressure. The operating cost will be a fraction of that incurred in running your present plant."

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Chromalox Units are made in so many forms, types and capacities, that practically every industrial heating problem to 1,000 deg. F. can be solved by their use.

As a primary source of seasonal heating for factory floors, rooms or offices, or as a secondary source, for providing heat during non-productive hours, (permitting boiler fires to be banked) chromalox-equipped Electric Unit Heaters are performing yeoman service everywhere. They provide heat when and where it is wanted, and their operation and installation are essentially simple. Built in sizes from 1.5 kw. to 40 kw.

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Send us a rough sketch and description of your problem

Mail with your business letterhead

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Without obligation, send me the CHROMALOX BOOK of ELECTRIC HEAT.

Name .....

Position .....

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Not One Close Clearance!

Revolutionary!—a superior product from every angle. Not a single close clearance in the entire design. No chance for rapid wear. As a result, lower operating and maintenance costs—longer service life—*much longer.* These Automatic REDI-VAC Pumps are preferred equipment wherever men are willing to listen to FACTS. Are you open to conviction? Then by all means read our Bulletin 441—FREE UPON REQUEST. And, yes, we build sizes to meet every vacuum heating requirement. AMERICAN STEAM PUMP COMPANY, Battle Creek, Mich.

AMERICAN-MARSH

CENTRIFUGAL AND STEAM PUMPS

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Pins—stampings—nuts and bolts—oranges—cans—bags—bottles—castings—cartons—anything a man can count and a good many things a man *can't* count can be recorded accurately and economically by a Veeder-Root counting device.

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HARTFORD, CONNECTICUT

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Material Handling Engineers

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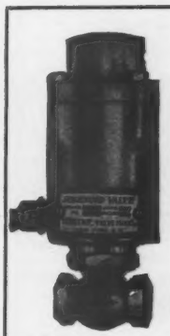

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ONE INEXPENSIVE MODERN DEVICE . . . .

installed at a crucial spot can frequently remove the "bugs" from an entire process.

It's the faster and surer electrical and mechanical "helps" and "hazard removers" that reduce costs and save company money.

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To be informed—and reminded—on modern aids to efficient and economical plant operation, check "Service Section" Advertising regularly . . . *every issue.*

For additional information write

Departmental Advertising Staff

FACTORY MANAGEMENT and MAINTENANCE

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Locate at switchboard or any desirable place. Comes complete with cord and connector, ready to install. This device will operate any type of signal or horn or siren. Write and let us give you complete details on the *Signal Kall.*

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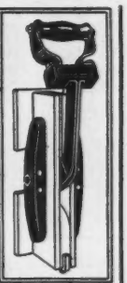

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THE AUTOMATIC RECLOSING CIRCUIT BREAKER COMPANY

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End 75% of Your Motor Troubles. Save Oil. Prevent Accidents

Feed just enough oil automatically. Never forget. Never slop. Correct the cause of most motor troubles. End oil dripping and accidents. Pay out quickly in oil and oiling time saved.

30-DAY FREE TRIAL

Constant Level, Thermal and Loose-Pulley Types. Send for dozen today on 30-day free trial—just indicate type or types wanted.

SpeedWay Mfg. Co.

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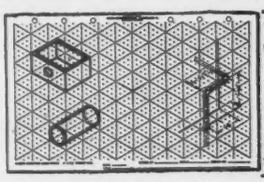

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If so, how many plants represented by the thousands of readers of Factory Management & Maintenance could use it too (and would BUY it) if your advertisement appeared here?

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89' x 535'	50' x 180'	50' x 160'

"We can adapt buildings to suit your Requirements"
Buyers and Sellers of Steel Buildings of All Kinds
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Brand New Westinghouse Motor Generator Set
200 hp., 3 ph., 60 cy., 220 v. synchronous motor direct connected to a 124.5 kw., 100% power factor, 120 v., 60 cy. single phase generator.
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Motors and Generators, A.C. and D.C. for sale at Attractive Prices. Large Stock. New and Rebuilt. All Guaranteed. *Write for Stock List and Prices.*
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FOR SALE
One fully automatic Munning **nickel plating machine.**
MUELLER CO., Purchasing Agent,
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A Complete Stock. **Prompt Shipment.**

6—500 KVA Gen. Electric Transformers, 60 cycle, 13200—240/480 volts. **$900.00** EACH

We Rewind, Repair and Redesign all Makes and Sizes.
ALL TRANSFORMERS GUARANTEED FOR ONE YEAR.

Write for Catalog No. 130-D

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"AMERICA'S USED TRANSFORMER CLEARING HOUSE"
STATION M **CINCINNATI, OHIO**

PARTIAL LIST OF MOTORS

Three Phase, 60 Cycle, Squirrel Cage

QU.	HP.	MAKE	TYPE	SPEED
1	20	Allis-Chal.	AN	860
1	20	Allis-Chal.-ball brg.	AN	860
2	20	Electric Dynamic	BK173	850
1	20	Fynn Weichsel	19TPN	720
2	20	Gen. Elec.	KT322	1150
1	20–5	Gen. Elec. 2 speed	KT322	1160/570
1	20	Gen. Elec.	IK	850
1	20	Valley		1200
1	20	Westgh.	CS556A	870
3	20	Westgh.	CS	860
1	25	Allis-Chal.		850
1	25	Fynn Weichsel	19TRN	720
3	25	Gen. Elec.	KT322	1150
2	25	Gen. Elec.	KT326	860
2	30	Diehl	168X	860
2	30	Fairbanks-Morse	H12B	1150
1	30	Gen. Elec.	KT512S	1800
1	30	Gen. Elec.	KT326	1160
8	30	Gen. Elec.	KT332	1200
1	30	West. Elec.	KT322	1150
1	30	West. Elec.	KT332	1150
1	30	Westgh.	CS	870
1	30	Westgh.	CCL	1120
1	30	Westgh.	CS	1160
1	35	Gen. Elec.	IK	1155
1	40	Allis-Chalmers	AR	850
1	40	Gen. Elec.	KT336	1160
1	40	Westgh.	CS	870
1	40	Westgh.	CS563C	1750
1	40	Westgh.	CCL	1120
1	40	Westgh.	CS	870
1	50	Burke	EM7	900
1	50	Westgh.	CS646C	1160
1	50	Westgh.	CCL	850
1	60	Gen. Elec.	KT346	850
1	60	Gen. Elec.	KT356	600
5	75	Crocker-Wheeler	124Q	690
1	75	Gen. Elec.	KT343	1200

We carry a large stock of transformers, motors, generators, engine generator units, turbo generators, etc.

What have you for sale? What do you need?

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SINCE 1902

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Hp.	Volts	Make	Speed
200	2200–440–220	G.E.	600
150	2200–440–220	G.E.	514
150	220–440–550	G.E.	600
150	2200–220–440	G.E.	720
100	220–440	G.E.	900
100	2200–550	Westghse.	900
100	550	Wagner	720
100	440–220	G.E.	720
100	550	G.E.	900
75	440–220	G.E.	900
75	220–440	G.E.	720
60	2200	G.E.	600

DIRECT CURRENT MOTORS

Hp.	Volts	Speed	Make	Type
250	230	700	G.E.	MPC
100	230	1150	G.E.	LC
100	230	625	Westghse.	SK
80	230	600	G.E.	RC
40	230	750	G.E.	RC

DIRECT CURRENT GENERATORS

Kw.	Volts	Speed	Make	Type
225	250	900	G.E.	MPC
100	250	725	Westghse.	SK
75	250	750	G.E.	RC
35	250	850	G.E.	RC

MOTOR GENERATOR SETS

1—250-kw., 250-v., 1200 r.p.m., G.E., type MPC, connected to type ATI, 435 hp., .8 PF-2300/4000-v., 60 cy., syn. motor.
1—200-kw., 250-v., 1200 r.p.m., G.E., type MPC connected to type TS, 350-hp., .8 PF-2300/4000-v., 60-cy., syn. motor.
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1—300-kva., 720 r.p.m., 2300-480-240-V., G.E.
1—225-kva., 900 r.p.m., 2300-V., G.E.
1—225-kva., 600 r.p.m., 2300-480-240-V., G.E.
1—200-kva., 900 r.p.m., 220-440-V., Westghse.
1—112½-kva., 1200 r.p.m., 2200-480-V., G.E.
1—100-kva., 900 r.p.m., 2300-V., Whse.
1—75-kva., 1200 r.p.m., 240-480-V., G.E.
1—75-kva., 1200 r.p.m., 240-480-V., Crocker-Wheeler.
1—75 kva., 900 r.p.m., 600-V., Westghse.

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- **Exchange**
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- **and Sizes**

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Always Dependable — Economical —

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1000 hp., G. E., Slip Ring, any voltage, 400 r.p.m., 3 ph., 60 cy.
800 hp., Westinghouse Syn., 4150 v., 180 r.p.m., 3 ph., 60 cy.
500 hp., G. E., Slip Ring, 4150 v., 3 ph., 60 cy., 720 r.p.m.
Smaller sizes on request.
2—200 kw. Ames Uniflow Sets.
Motor Generator Sets.
Turbines & Engine Sets.
Transformers.
D.C. Motors & Generators.

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803 Williams St., North Bergen, N. J.

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53 West Jackson Boulevard, Chicago, Ill., Chicago Representative.

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—to help you sell what you no longer need.

Take Advantage Of It

For Every Business Want

"Think SEARCHLIGHT First"

G-7

MOTORS 3 PH., 60 Cy.			ENGINE GENER.
Hp.	Type	Speed	1-400 kva., Cr. Wh., 240 v., 3 ph., 60 cy., 120 r.p.m. to Hamilton Corliss Engine.
1000	G.E. Syn.	360	
600	G. E. sl. rg.	720	ROTARY CONVERTER
2-600	G. E. sl. rg.	252	1-500 kw., G.E. Type HCE, 250 V., D.C. 6 ph., 60 cy., 1200 r.p.m. Complete with transf.
600	G. E. syn.	257	
600	Al. Ch. syn.	240	
1-675	Al.Ch. syn.	900	
400	West. sl. rg.	514	
400	West. sl. rg.	505	CENTRIF. PUMPS
300	G. E. sl. rg.	575	1-1400 G.P.M., 150' Head dir. conn., 675 hp. Al. Ch. 900 r.p.m. syn. motors.
300	Al.Ch. sl. rg.	585	
260	Al.Ch. syn.	720	
200	G. E. syn.	900	1-14,000, G.P.M., 60' Hd., dr. conn. 260 hp., Al.Ch. 720 r.p.m.
2-200	West. sl. rg.	900	
200	G. E. sl. rg.	900	
150	West. sl. rg.	720	
100	Al. Ch. sl. rg.	695	

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(Since 1899)

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NEW YORK CITY

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The service of the consulting engineer is a real economy. With his knowledge of organization and production problems and his wide and varied experience, he can usually reveal the points of waste and inefficiency that are costing you money and suggest inexpensive means for their elimination.

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